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The reestablishment of wetland communities by remnant wetlands, long-distance dispersal, and seed banks on the Kissimmee River floodplain, Florida

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The reestablishment of wetland communities by remnant wetlands, long-distance dispersal, and seed banks on the Kissimmee River floodplain, Florida

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has meet the thesis requirements of Iowa State University

Signatures have been redacted for privacy

To Mom & Dad

Giving me faith in God,
Confidence in myself and
Your love of nature

To make you proud

Love always,

Erin

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ABSTRACT

This study investigates four potential sources of propagules by which plant species formerly dominant in three major wetland communities might become reestablished on the Kissimmee River floodplain, FL. Three sources of propagules studied were dispersal from remnant populations of wetlands on the floodplain, long-distance dispersal of seeds and propagules from upstream, and seed banks. Eight wetland indicator species, dominants in the three wetland communities that formerly covered the pre-channelized floodplain were selected for study. The potential significance of relict wetland populations, long-distance seed dispersal and seed banks as propagule sources for these indicator species was examined through logistic regression analysis. The response variable was the colonization status of a species in a quadrat. The effect factors or sources of propagules were dispersal from remnant wetlands, long-distance dispersal from upstream, and the seed bank. All three of these sources of propagules were statistically significant for the reestablishment of these indicator species. The data suggests the seed bank and remnant wetland propagules were sufficient sources for most species studied. When species are not found in the vegetation or seed bank, species may rely on long-distance dispersal. Long-distance dispersal is achievable since most species are distributed throughout the floodplain. Some areas are isolated with few remnant sources near by and some areas were converted to cattle pastures or sod farms and are highly degraded. These areas may take longer to reestablish.

INTRODUCTION

Study Rationale

Restoration is the process by which a destroyed or degraded ecosystem is returned to a close approximation of its prior condition. The reestablishment of flood pulsing or seasonal floodplain inundation is the first step in the restoration of drained riverine wetlands and is essential for reestablishment of its vegetation, wildlife and functional dynamics. Flood pulsing creates predictable seasonal changes in the water flow of a stream in which the biota are adapted (Junk 1982,1997; Junk and Howard-Williams 1984; Junk et al. 1989; National Research Council 1992; Bayley 1995). Ecosystem features such as primary production, food chains and mineral cycling are a function of floodplain hydrology (Sparks et al. 1990). Among other things, flooding creates a connection between the river channel and floodplain that allows seeds and other propagules far upstream to reach the floodplain (Finlayson et al., Niering1994, Middleton 1999a, 2002). Flood pulsing also creates favorable conditions that enable wetland plants to establish and survive. While high water stages are critical for the dispersal of seeds, low water levels provide the moist soil environment required by many wetland species for establishment (Junk and Piedade 1997; Middleton 1999b, 2000). Although the importance of flood pulsing for floodplain restoration is gaining acceptance, some evidence does suggests restoring flood pulsing cannot alone restore function (Brooks et al. 1996). For example, reestablishment of the original hydrology may not be enough to restore the vegetation in a wetland if physical and chemical conditions of the soil are degraded (Haltiner et al. 1997).

Throughout most of the world, very few rivers still have a natural hydrologic regime. Most have been engineered to some extent for flood protection and floodplain utilization. At a minimum riverine wetland restoration requires reverse engineering to re-create a river's natural hydrology. Such re-engineering is often impossible because of human encroachment of floodplains. However, the ongoing restoration of the Kissimmee River floodplain, Florida is an exception because relatively little of the drained floodplain became developed, most was converted to pasture. The goal of the Kissimmee River restoration is to reestablish the historic pre-channelization hydrology (flood pulsing) and the physical, chemical and biological characteristics of the river and its floodplain. The historic Kissimmee River floodplain vegetation was a mosaic of three wetland communities; wet prairies, broadleaf marshes, and wetland shrubs. River channelization in the 1960s resulted in the drainage of the floodplain and a significant reduction in its wetlands and their waterfowl, fish, and invertebrates.

The restoration of the pre-drainage hydrology of the river is expected to be sufficient to reestablish former wetland vegetation types and their associated fauna. This implies the propagules needed to reestablish all three wetland vegetation types are already established on the floodplain or will be quickly dispersed onto the floodplain after hydrology is restored.

Although the channelization of Kissimmee River floodplain was effective for flood protection, it also reduced the coverage of wet prairie, broadleaf marsh, and wetland shrub vegetation by 48%, 86%, and 77%, respectively (Toth et al. 1995). Some low-lying areas of the floodplain continued to be inundated periodically during the wet season. Consequently, the vegetation of the pastures and other areas of the drained floodplain are expected to contain some wetland species, at least periodically, when conditions are suitable.

The goal of this study is to investigate three potential sources of propagules by which plant species that formerly dominated the three major wetland communities might become reestablished on the Kissimmee River floodplain: dispersal from remnant populations of wetlands on the floodplain, long-distance dispersal of seeds and propagules from upstream, and seed banks.

The potential significance of relict wetland populations, long-distance seed dispersal and seed banks as propagule sources will be examined using logistic regression analysis. These analyses are used to estimate the probability a given wetland species is present in an area due to its proximity too relict populations, due to long-distance dispersal, and due to its presences in the seed bank. When one or more of these sources of propagules are present, this will increase the probability a wetland species will be reestablished in an area.

Land use on the drained floodplain varied from place to place. For example, some areas were drained earlier than others, (i.e. Mac Arthur Impoundment), and some areas were highly degraded in sod farming. Although most of the post-drainage floodplain was converted to pasture, shrubs, primarily *Myrica cerifera* or Wax Myrtle/ Bayberry, invaded some poorly drained areas. How different land uses might affect the probability of species re-establishment will also be examined.

Background/Literature Review

The study site: Kissimmee River floodplain

The Kissimmee River basin is the headwaters of the Florida Everglades system. It originates in a 4229 km^2 catchment with 26 interconnect lakes, including Lake Kissimmee, just south of Orlando. The river empties into Lake Okeechobee, the second largest freshwater lake within the United States. Historically, the Kissimmee River meandered 166 km with a 1.5-3 km wide floodplain (US Army Corps of Engineers 1992). The river's floodplain underwent a seasonal wet-dry cycle, i.e. flood pulsing, typical of subtropical regions in which periods of high flow and flooding during the summer months were followed by periods of low flow and drying during the winter months. Due to the river's poor outlet capacity, periodic flooding events transformed the river into a wide and shallow lake. Flood duration and elevation data indicate the floodplain was inundated over 50% of the time. Water depth typically ranged from 0.3-0.7m, but some areas had depths greater than 1 meter (Toth 1990). These conditions supported three wide spread wetland communities on the floodplain; wet prairies, wetland shrubs, and broadleaf marshes plus a diverse fauna.

Prior to the river's channelization in 1940, human settlement within the river basin was sparse with some farming and cattle ranching. Significant population growth and economic development took place in the area after World War II. Unfortunately, this occurred in conjunction with severe hurricanes, especially in 1947, which resulted in extensive flooding from 1947 to 1949. Public pressure grew to reduce the threat of flood damage within the basin (U.S. Army Corps of Engineers 1992). In 1948, Congress approved the Central and South Florida Project for flood control to be undertaken by the U.S. Army Corps of Engineers. Between 1962-1971, the Kissimmee River was channelized to provide protection from damaging floodwater and to make central Florida more suitable for agricultural/ residential development. The Kissimmee Flood Control Project transformed the river in to a 9-m deep, 100 m wide drainage canal approximately 90 km-long. Dikes divided the floodplain into a series of reservoirs. As a result of this channelization, as much as 2/3 of the river-floodplain ecosystem was negatively impacted (Koebel 1995). Historic water-level fluctuations were greatly reduced. Immediately noted, impacts included drastic population declines in fish, birds, and other wildlife. It is estimated game fish such as the largemouth bass, black crappie, and forage fish decreased by billions. Water birds and wading birds are reported to have decreased by over 90% (Toth 1990).

Concerns over the decline of fish and wildlife populations resulted in the Kissimmee River Restoration Project, which was authorized by the 1992 Water Resources Development Act. The restoration will involve approximately 100 km^2 of river-floodplain ecosystem, including 70 km of contiguous river channel and over 11,000 ha of floodplain wetlands. Major components of the project will include; re-establishment of historic inflows, backfilling 35 miles of canal, removal of dikes, and re-carving 14 km of historic river channel. Construction began in 1997 and its completion is anticipated in 2010. This project is the largest wetland restoration undertaken to date (Dahm et al 1995). The Kissimmee River project will be scrutinized for years to come. Its success will be judged largely by how successful flow in the restored river channel and floodplain are restored. For former wetlands on the floodplain, it is assumed the re-engineering of their former hydrology will result in the re-establishment of historic wetland vegetation due to relict wetland populations, long-distance dispersal or seed banks (Dahm et al. 1995). Therefore, the reestablishment of historic wetland vegetation on the floodplain will be used to judge the projects success.

Wetland vegetation of the Kissimmee River

The most widespread vegetation communities on the Kissimmee River floodplain historically, i.e., prior to channelization, were wetland shrub, broadleaf marsh, and wet prairie (Wetzel et. al 2001). These communities were distributed along an elevation gradient from the banks of the river channel to the edge of the floodplain. Wetland shrub and broadleaf marsh vegetation found in areas permanently or frequently flooded. Wet prairie communities dominated areas near the edge of the floodplain that were seasonally inundated. After channelization, wetland shrub and broadleaf marsh communities declined by 86% and 77% respectively on the floodplain. Wet prairie communities also declined about 50%. This left a small proportion of post-channelization remnant wetland communities to persist on the floodplain in poorly drained areas. The effectively drained areas were usually converted to pasture, covering approximately 44% of the total floodplain (Pierce et al. 1982).

Restoration of wetland communities

Wetland restorations are executed in a variety of ways. Nationwide, most restored wetlands are re-vegetated actively through seeding and planting. In fact, planting vegetation is a critical step in most restoration projects (Committee on the Restoration of Aquatic Ecosystems 1992). In the prairie pothole wetlands, however, some early studies suggested wetlands could be restored simply by restoring their hydrology (Madsen 1986). The idea re-establishment vegetation will occur after its hydrology is restored is referred to as the "efficient community hypothesis" (Galatowitsch and van der Valk 1996). According to this hypothesis, all species able to established and survive under the environmental conditions found at a site will eventually be found there. It is also expected the former wetland communities along the Kissimmee River floodplain will re-establish, without any assistance (Toth et al. 1995). Recreating the historic hydrology, including river-floodplain connections, is expected to enable the return of historic wetland vegetation types to areas of the floodplain where they occurred prior to the channelization (Toth et al. 1995).

Restoration of the Kissimmee River floodplain

Re-establishing the historic hydrology, including the river-floodplain connections is expected to enable the return of all three wetland vegetation types in the same areas of the floodplain where they occurred previously. Broadleaf marsh communities are expected to re-establish, approximately 2-3 years after inundation begins. *Cephalanthus* wetland shrub communities will also re-establish quickly, < 3 years, in areas of the floodplain where they were replaced by upland or mesophytic shrubs. Wet prairie communities that are expected to re-develop in peripheral areas of the floodplain are expected to take 3-5 years to reestablish. This lag time is because many upland and mesic prairie species in pastures may persist (Toth et al.1995).

A relict seed bank, containing the seeds of wetland species, enhances the potential for historic vegetation restoration in wetlands (Weinhold & van der Valk 1989). The seed banks of the Kissimmee River contain seed from most of the dominant historic wetland species. An early study of the Kissimmee River wet prairie vegetation (Goodrich and Milleson 1974); found 45% of newly emerged species were present in the seed bank samples. Recently, the potential role of wetland seed banks in the re-establishment of the historic wetland communities on the Kissimmee River floodplain was examined by Wetzel et al. (2001). Similarly, they found half of the species which makeup wet prairie were present in the seed banks of former wet prairie sites. According to these results, seed banks should play a significant role in the re-establishment of wet prairie species. For broadleaf marsh sites, however, only one characteristic species could be found in the seed banks and for wetland shrub sites no characteristic species were found.

For all three historic vegetation communities, especially broadleaf marsh and wetland shrub, a complete restoration of the historic species for most areas on the floodplain will require propagule dispersal from other areas (Wetzel et al. 2001). One potential source of propagules is remnant populations of wetland species whose seeds can be dispersed via wind, water, and animals to the rest of the floodplain (Schneider and Sharitz 1988). Remnant wetland communities, which survived the river channelization, are scattered over the Kissimmee River floodplain. McQuilkin (1940) determined the rate of vegetation redevelopment on a disturbed site is often related to the distance to stands of natural vegetation. The closer the natural vegetation is to a given disturbed site, the sooner the site will be restored. Many studies have shown a negative exponential relationship between the probability of seeds being dispersed and the distance from the source plant (Werner 1975, Greene and Johnson 1986). Remnant wetland communities can accelerate localized recovery of nearby areas. This is referred to as the 'rescue effect' by Brown and Kodric-Brown (1977). Species will have a greater probability of re-establishment at a site if a relict population of these species is in close proximity.

Dispersal of seeds over the floodplain by river flooding can also bring propagules from far away out on the floodplain. During a flooding event, seeds can be transported long distances from upstream source communities to downstream areas. Continuous river corridors are important for maintaining the species biodiversity of floodplain vegetation. In regulated rivers, fragmented by channels and dams, upstream and downstream community similarity decreases after regulation. This decrease in similarity is due to restriction of hydrochory (Nilsson and Jansson 1995). Studies have reported seeds and propagules can be dispersed distances of 5 km (Johansson and Nilsson 1993). Certainly, hydrochory was an important mechanism for seed dispersal on the pre-channelized Kissimmee River floodplain.

Historical flood-stage data indicate the floodplain was exposed to prolonged flooding. The frequencies of inundation varied from year to year, but the hydroperiods were longest in areas adjacent to the river channel (Koebel 1995). It is predicted that frequently flooded areas of the floodplain will have a greater probability of re-establishment of historical vegetation due to long distance dispersal of seeds and propagules by hydrochory. Areas closer to the river and at lower elevations will have a greater chance of inundation. It follows that former vegetation types found closer to the Kissimmee River and in areas at lower elevations will have a higher probability of re-establishment due to long-distance dispersal.

Study Objectives

It is predicted the former wetland vegetation on the Kissimmee River's floodplain will re-establish naturally after its hydrology or flood pulsing regime is restored. Three potential sources of propagules through which species can re-establish are the focus of this study (Figure 1). One, species may re-colonize areas from nearby relict wetland communities, (short and intermediate-distance dispersal). Two, seeds or propagules of species can be dispersed to areas from upriver by the periodic floodplain inundation of the river, (long-distance dispersal). Three, seeds of these species may present in the seed bank of an area, (seed bank). When these sources of propagules are available, it is expected that the probability a wetland species is already present in an area will be greater. In other words, it is assumed that these different dispersal mechanisms were obtainable after channelization, but were much less effective.

Eight wetland indicator species, dominants in each of the three-wetland communities that formerly covered the Kissimmee River floodplain (Toth 1995), were studied. Logistic regression analysis can be used to determine how well the presence given wetland indicator species in an area, (permanent quadrat), can be predicted from an examination of the three potential sources of propagules. The presence of indicator species can be predicted if a correlation exists between a source of propagules and the presence of a given wetland species in a series of 48 permanent quadrats on the floodplain.

The probability of a given wetland species being present in an area due to its proximity to relict populations was estimated by short-distance dispersal and intermediate-distance dispersal. The role of relict populations for short and intermediate-distance dispersal was evaluated directly. Short- distance dispersal is from relict populations 100 m around each quadrat for relict wetland wetlands with indicator species. Permanent quadrates with an indicator species growing in relict wetlands within 100 m of the quadrate were expected to have a greater probability of having an indicator species an indicator species. Intermediate-distance dispersal was evaluated through determination of the total propagule source area or the total area containing an indicator species within 200m of a quadrat. GIS vegetation maps of the Kissimmee River floodplain based on 1996 aerial photography were available to estimate the total propagule source area. More propagule source area for an indicator species around a quadrat should result in a greater the potential a species will be found in a quadrat. This assumes species are uniformly dispersed throughout the floodplain and they will be dispersed in the direction of the quadrat. Short-distance dispersal from field observations was included in the study since GIS vegetation maps may fail to notice some smaller relict sources of propagules.

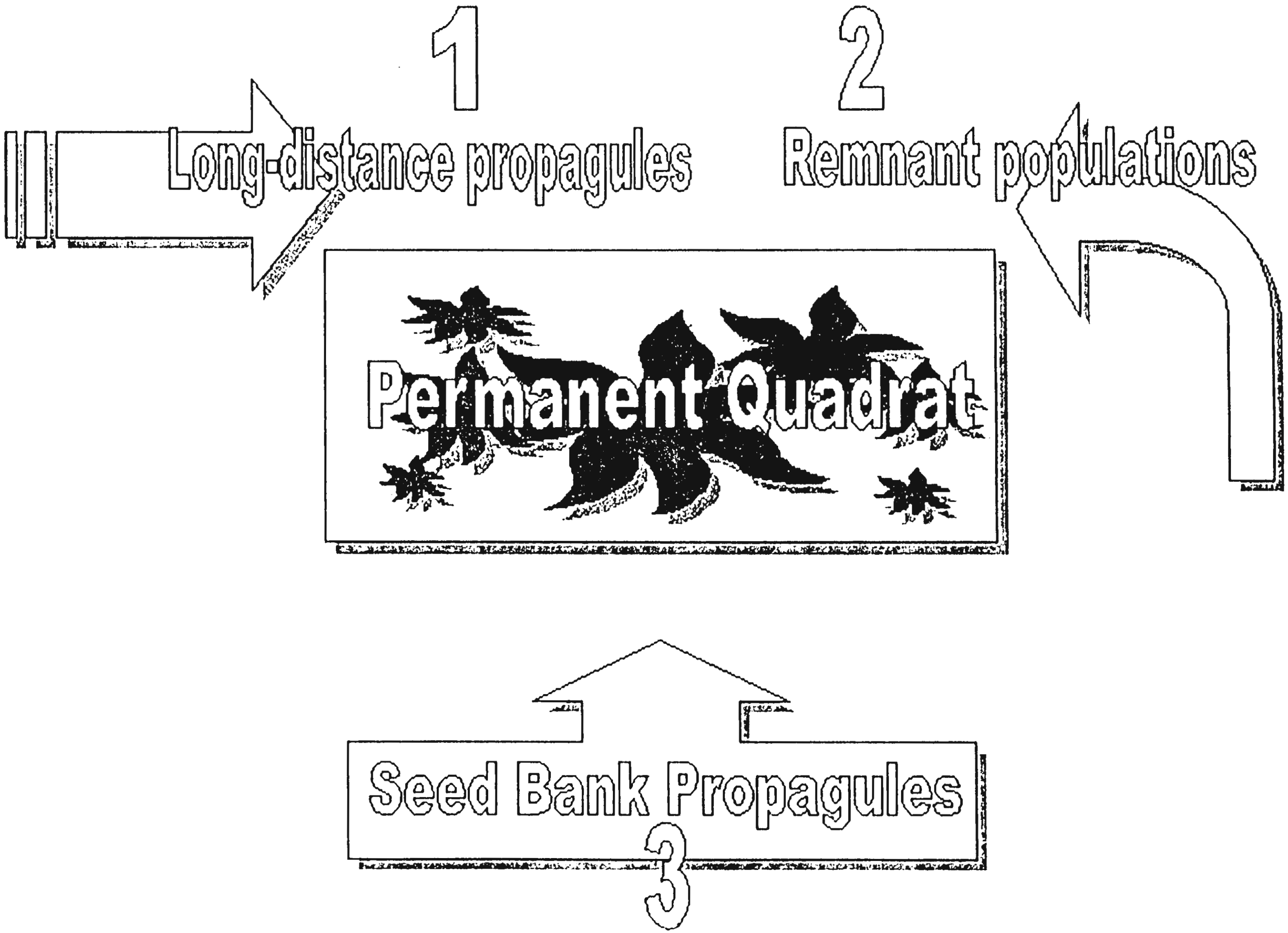
The role of long-distance dispersal or the role of wetland species dispersed to areas from upriver by the periodic floodplain inundation of the river was not evaluated directly. Instead, absolute elevation of a quadrat and distance from the quadrat to the nearest river channel was used. Quadrats at lower elevations should have a greater potential to be flooded and be more likely to have wetland species dispersed to them from upriver. Likewise, quadrats closer to the river channel should have a greater flood potential and be more likely to have wetland species dispersed from upriver. Quadrats at lower elevations and quadrats closer to the river were expected to have a greater potential to contain any given indicator species. Three assumptions are made regarding long-distance dispersal. First, floodwaters contain viable propagules of all wetland species being evaluated. Second, small populations of wetland species are re-established periodically at low densities on the floodplain. Third, the water disperses the propagules in a gradient over the floodplain concentrating propagules more in flood prone areas.

The potential role of the seed bank on re-establishment of wetland communities can be evaluated directly by examining the presence or absence of a given species in the seed bank of the quadrats. If an indicator species is present in the seed bank of a quadrat, it should have a greater potential to contain that species. This assumes the seed bank is viable and conditions are meet for germination.

When more than one source of propagules are available, it is expected the probability a wetland species is present in an area will be greater. Nevertheless, the role of remnant wetlands, long-distance dispersal, and the seed bank as propagule sources will be separately analyzed using logistic regression. Sources of propagules of each species will be independently evaluated to determine their potential role for the reestablishment of a given species in areas where it was prior to the channelization. This will decide if certain species or communities will have difficultly in reestablishing areas of the floodplain and suggest why.

It is probable the post-channelization land-use or vegetation cover will complicate the restoration of the Kissimmee River. The post-channilization land-use and vegetation cover varied considerably from place to place. For example, some areas of the floodplain were sod farmed while other areas were unaltered. The effect of post-channelization land-use or vegetation cover will be examined. It is expected quadrats in highly degraded areas; such as sod farms will be less likely to contain wetland indicator species. Simply restoring the hydrology may not be enough to restore the vegetation in a wetland if the soil is both physically and chemically degraded.

Figure 1: Three sources of propagules to reestablish quadrats on the Kissimmee River floodplain; long-distance dispersal of seed/ propagules, nearby remnant wetland popaulations, and seed bank propagules.



MATERIALS AND METHODS

Species Studied

Eight wetland indicator species that were dominants in each of the three-wetland communities that formerly covered the Kissimmee River floodplain (Toth 1995) were selected for study. For the wetland shrub community *Cephalanthus occidentalis* (buttonbush) was selected as an indicator species. For the broadleaf marsh community, two species were chosen, *Pontedaria cordata* (pickerelweed), and *Sagittaria lancifolia* (lance-leaf arrowhead). For the more diverse the wet prairie community, five taxa were selected; *Eleocharis spp.* (spikerush), *Juncus effusus* (soft rush), *Panicum hemitomon* (maidencane), *Polygonum spp.* (smart weed), and *Rhynchospora inundata* (horned beakrush) (Table 1). *Eleocharis* and *Polygonum* species in grazed pastures could not be reliably identified to species.

Permanent Vegetation Quadrats

Permanent vegetation quadrats were established by South Florida Water Management District (SFWMD) to monitor changes in the composition of the floodplain before and after restoration. A total of 83, 5 x 20 m quadrats were systematically scattered throughout the floodplain in Pool C where wet prairie, broadleaf marsh, and wetland shrubs had existed prior to channelization. Historic vegetation distributions were estimated through interpretations of black-and-white aerial photography (1952-1954). Quadrats were sited within the floodplain based on historical vegetation, post-channelization land-use, existing vegetation, and elevation. Post-channelization land-use practice varied considerably along the floodplain, Table 2. In theory, the historic, i.e., pre-channelezation plant communities found at each location are expected re-develop within each quadrat.

Vegetation sampling has documented plant species composition, cover, and diversity annually for several years after in many permanent quadrats prior to 2001. Lou Toth, of the Kissimmee Division of the SFWMD, collected data on the presence of indicator species in quadrats during sampling period in May-June, 2001. From this survey, a complete list of all the species present in the quadrats, i.e., species composition was available. This data was used to determine if indicator species were already established in the quadrats.

Data Collection

Remnant wetland propagules: short-distance dispersal

To determine if propagules were present in remnant wetlands near the permanent quadrats, the area around the 48 quadrats was surveyed in early summer (May to June) 2001. Quadrats were located within seven sites; Mac Aurthur Impoundment, EC Slough Zone, Wax Myrtle, Montsdeoca Pasture, NE Sod Farm, NC Shrub, and NW Pool C Pasture (Figure 2). The area around each quadrat was examined 100m from the center of the quadrat. All relict or remnant wetlands within a 100m radius of the quadrat were noted as was the presence of any indicator species.

Remnant wetland propagules: intermediate-distance dispersal

Remnant wetlands within 200m of the quadrat were considered sources of propagules available for intermediate dispersal. The SFWMD developed GIS vegetation maps from1996 aerial photography of the Pool C, followed up with ground-truthing. A complete map of the river channels and floodplain in Pool C was available. This included attribute tables listing dominant wetland species found in all areas mapped on the floodplain. The potential for intermediate distance dispersal, was evaluated using these attribute tables. Circles with a 200m radius were drawn around each quadrat, (circles with larger radii created too much overlap with circles from nearby quadrats). A map of the NE Sod Farm Site, (Figure 3) illustrates the sampling around quadrats 103 and 111. It was assumed that a given species in the attribute table for a polygon was uniformly distributed across the entire polygon, i.e., that the area of a polygon within the circle was an estimate of the abundance of an indicator species.

Long-distance propagules: distance from the river channel

Long distance dispersal is the ability of seeds and propagules from wetland communities upstream to travel downstream and re-establish vegetation to other areas of the floodplain. The potential for long distance dispersal was estimated by the distance in between each permanent quadrat and the nearest channel of the Kissimmee River in meters (Figure 2). Areas closer to the river channel have a greater chance of being flooded with seeds and propagules than areas greater distances from the river channel. The potential for long - distance dispersal was analyzed using the same GIS maps mentioned earlier.

Long-distance propagules: elevation

Sites at lower average elevations are expected to be flooded more frequently, and have a better chance of receiving long-distance dispersal propagules and seeds. The SFWMD provided elevation data for all the quadrats. The four corners of each quadrat were measured to the 0.1m using GPS. These measurements from the four corners were used to calculate a mean elevation for each of the quadrat studied (Appendix 1).

Seed bank propagules

A species can re-establish in a plot from its seed bank. Seed bank sampling occurred in the fall 1998 and in the spring 1999. At each research quadrat, 12 cores of soil were cut from around the perimeter of the quadrat with a golf hole cutter. Each hole was approximately 12.5 cm in diameter and 10cm deep. These soil samples were combined together and mixed to make one composite sample for each research quadrat. The composite sample was divided up evenly into six pots. The soil was placed on a layer of sterile sand. Three pots were placed under a flooded treatment and three pots were placed under a saturated soil treatment. A flooded treatment was created by drillings holes in containers above the soil layer and putting them into shallow pools allowing them to flood. Water covered the soil at all times. A saturated treatment was created by drilling holes in the containers beneath the soil layer and placed in shallow pools with the soil layer just above the water. The soil was moist at all times. Seeding emergence was recorded for nine months, all counts were standardized to 1 m^2.

Land-use practice

Different areas within the floodplain had different vegetation cover and different uses prior to restoration. Land-use practice and pre-restoration vegetation cover was derived from 1973-1974 aerial photographs by the SFWMD. Land-use and vegetation cover categories include; pasture, upland herbaceous, sod farm, levee, wet prairie, and mesophytic shrubs.

Data Analysis

Nominal logistic regression

Statistical analyses were performed to determine if the seed bank, and short, intermediate, and long-distance dispersal had a significant correlation with an indicator species' presence in a quadrat. A nominal logistic regression model was chosen based on the nature of the data. The response variable was the colonization status of a species in a quadrat. This colonization status was a categorical variable since a species was either present or not in the quadrat in 2001. Therefore, the response variable theoretically could have a value of 0, (species not present in quadrat), or 1, (species present in a quadrat). The effect factors or sources of propagules were remnant wetlands, long-distance dispersal from upstream, and the seed bank. The potential of propagules from remnant wetlands was estimated by; the presence or absence of an indicator species within 100 m of the quadrat (short-distance dispersal) and the area of remnant wetlands in which a species is found within a 200m of a quadrat (intermediate-distance dispersal). The potential for long-distance dispersal were estimated by the elevation of the quadrat, and the distance from the center of the quadrat to the Kissimmee River. The seed bank data was estimated by the number of individuals of a species in the fall and the spring seed bank samples. All effects were all continuous numerical variables except for short-distance dispersal, which was categorical. Indicator species either found or not found within 100m of the quandrat giving the value of 1 or 0 respectively. For each indicator species, a nominal regression model was fit for each source of propagules to the presence/ absence of an indicator species in a quadrat.

The six effects were fit individually for each indicator species with JMP software. A Chi-square test was used to confirm the statistical significance of the effect of each factor or source of propagules on the probability an indicator species was present in the quadrats. Chi square values of 95-100% were considered significant, values 95-90% were considered suggestive, and less than 90% were considered not significant.

Post-channelization land-use practice

Land-use practice prior to restoration and its correlation with species present in a quadrat was also examined. The pre-restoration land-use and vegetation cover of the area is designated a its pre-restoration land-use or vegetation cover. Pre-restoration land-use for each study area, (Table 2), was based on 1973-1974 aerial photography and ground observations. The percentage of quadrats re-established with the indicator species as of summer 2001 is compared within the various land use practices. On the basis of these comparisons, pre-restoration land-use practices unfavorable or favorable to species re-establishment should be apparent.

Distribution of indicator species

The distribution of the 8 indicator species throughout the floodplain is examined by looking for its presence in quadrats where it was and was not expected . The expected quadrats are classified as previously mention, quadrats that historically included the indicator species. Not-expected quadrats include all the other quadrats where the indicator species was not historically found. A comparison is made to determine if the potential of an indicator species in the quandrats of expected plots is similar to not-expected quandrats. A comparison will be made to determine if potential for relict wetland propagules may be similar for both expected and not expected quadrats. Finally, a comparison will be made between the seed banks of the expected and not expected quadrats.

Table 1: Community affiliation, description, and distribution of the indicator species (Florida Department of Environmental Protection 1998).

Vegetation community type *Indicator Species* **(Common Name)**	**Brief description**	**Distribution**
Wetland shrub		
Cephalanthus occidentalis (Buttonbush)	Shrub or small tree up to 10 ft tall; deciduous opposite or whorled leaves; round, white, bisexual flowers; Obligate to wetlands, (shrub)	Eastern Canada to MN, south to FL and TX
Broadleaf marsh		
Pontedaria cordata (Pickerelweed)	Herbaceous plant with long petioles, lance shaped leaves; stands 3 ft tall, blue spike of flashy flowers; Obligate to wetlands, (perennial)	TN, SC, FA, FL, TX, WI, South America
Sagittaria lancifolia (Lance-leaf arrowhead)	Herbaceous plant with erect, basal, lance-shaped leaves; usually over 3 ft tall, flowers are white; Obligate wetland species, (perennial)	Coastal plain, DE and ME south to FL, west to TX and OK
Wet prairie		
Eleocharis vivipara (Viviaparous spikerush)	Clumped herb with sheath-like leaves; inflorescence single terminal spikes; Obligate to wetlands, (perennial)	Coastal plain, VA to FL
Juncus effucus (Soft rush)	Clumped herb with split-open leaves, lengthwise, terminal dense flowered inflorescence; Obligate to wetlands, (perennial)	cosmopolitan
Panicuim hemitomon (Maidencane)	Very tall grass up to two meters; erect stems and loose leaves; Obligate to wetlands, (perennial)	Coastal plain, NJ to FL, TX, TN, tropics
Polygonum punctacum (Dotted smartweed)	Herb with alternate leaves and swollen nodes; up to 1-½ meters in height; Obligate to wetlands	Temperate and subtropical North America, tropical America
Rhynchospora inudata (Horned beakrush)	Leafy clumped herb with closed leave sheaths; soft spikelet clusters; Obligate to wetlands, (perennial)	Coastal plain, NC to FL west to TX, Bahamas, Cuba

Table 2: Pre-restoration land-use practices in areas with quadrats that were historically wet prairie, broadleaf marsh or wetland shrub.

Community type	Area	Pre-restoration land-use practice	Sample quadrats #
Wet Prairie	NW Pool C Pasture	Pasture	1, 2, 3, 5, 6, 122, 123, 125, 202
	Montsdeoca Pasture	Pasture	30, 34, 35, 36, 37, 140
	NE Pool C Sod Farm	Sod farm	101, 102, 103
	Mac Authur Impoundment	Pasture	222, 223, 224
Broadleaf Marsh	NE Pool C Sod Farm	Sod farm	108, 110, 111
	Pool C Wax Myrtle	Mesophytic shrubs	163, 165, 166, 169, 171, 172
	EC Slough	Upland herbaceous	174, 176, 178, 179, 180, 182
	Mac Arthur Impoundment	Mesophytic shrubs	217, 218, 348
	Mac Arthur Impoundment	Levee	350, 351, 352
Wetland Shrub	NC Pool C Shrub	Mesophytic shrubs	8, 9, 13, 14, 15, 116
	Montsdeoca Pasture	Wet prairie	20, 31, 33, 40, 136

Figure 2: Kissimmee River Pool C location within the state of Florida and the different pre-restoration land-use practices within Pool C: Wax Myrtle, Mac Authur Impoundment, Montsdoeca Pasture, Northeast Sod Farm, North Central Shrub, Northwest Pool C.

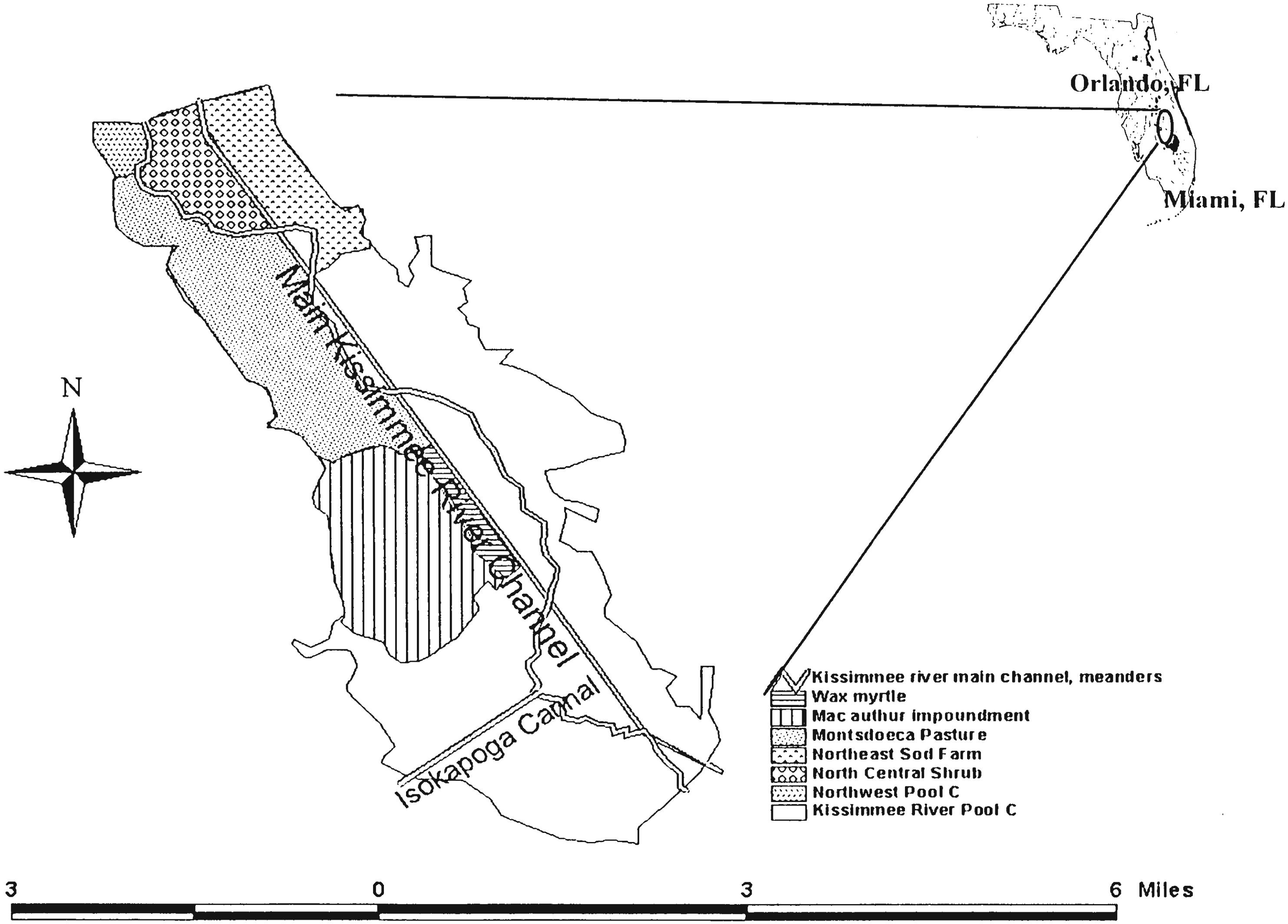
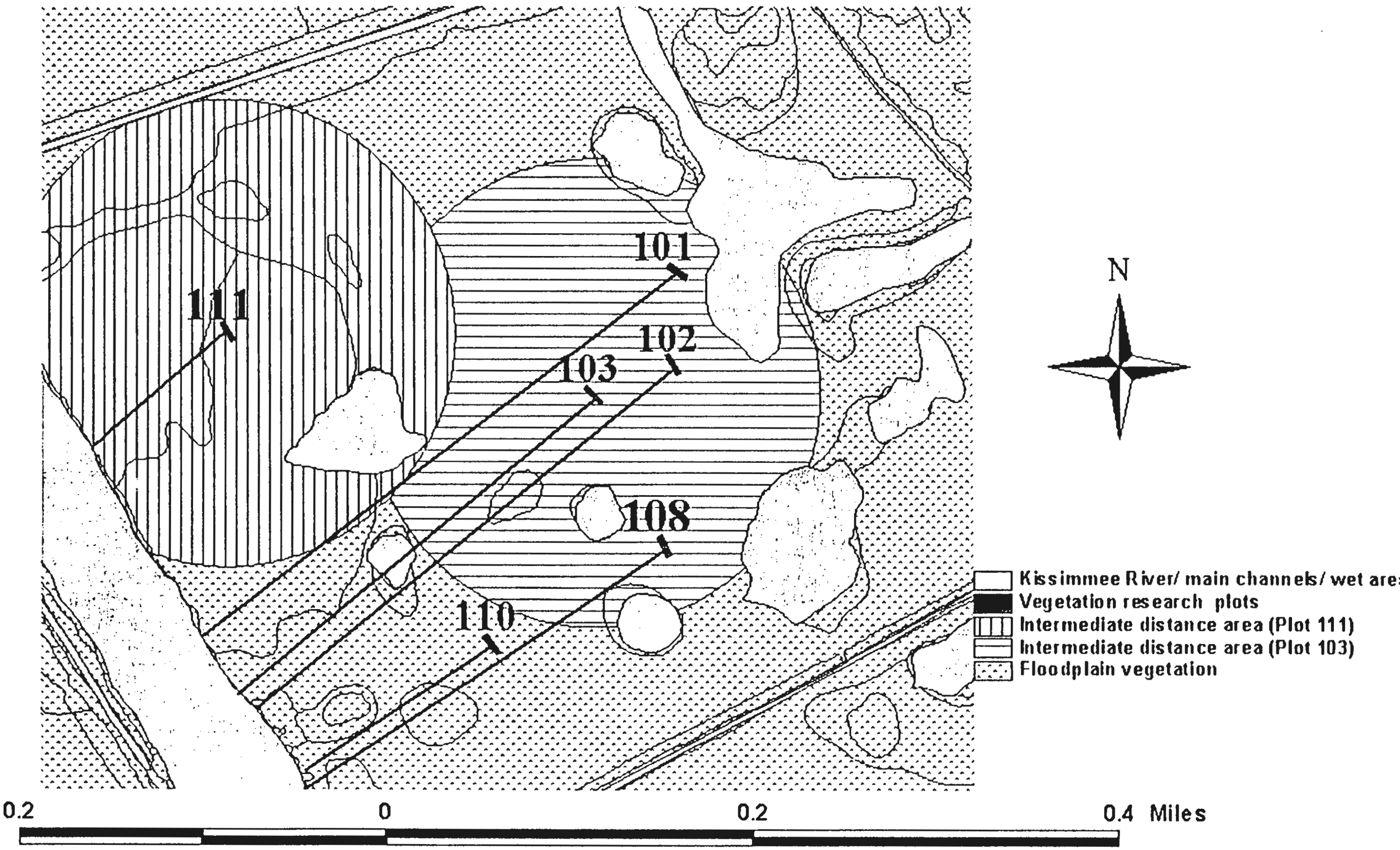


Figure 3 : Example of data collection at NE Sod Farm. Research quadrats (plots 111, 110, 108, 103, 102, and 101) locations, distances measured to the river channel, intermediate-distance remnant wetland areas for research quadrats 111 and 103.



RESULTS

Logistic Regression Analysis

The results from nominal logistic regression analyses are shown in Tables 3 and 4. The five different estimates of propagule sources; elevation, distance to the river, short-distance dispersal, intermediate-distance dispersal, and presence in the seed bank were found statistically significant (< 0.05) for two or more of the indicator species (Table 3). Presence in the seed bank is divided into three categories, the fall (1998), the spring (1999), and either the fall or spring seed bank.

Short-distance dispersal propagules

Short-distance dispersal, a measure of the potential of seeds and propagules from nearby wetlands within 100m of the quadrats to re-establish was statistically significant for four indicator species (Table 3 and 4). *Polygonum*, *Rhynchopora*, *Pontedaria*, and *Sagittaria.* They commonly were found in quadrats having nearby relict wetlands. This included both broadleaf marsh species and two wet prairie species.

Intermediate-distance dispersal propagules

Intermediate distance dispersal, a measure of the potential of seeds and propagules from up to 200m from quadrats was also significant among four species (Table 3 and 4). *Eleocharis*, *Rhynchospora*, *Pontedaria*, and *Sagittaria* were more likely to be in quadrats the greater the area of relict wetlands within a 200m radius. This also included both broadleaf marsh species and two wet prairie species.

Long-distance propagule sources: elevation and distance to the river

Elevation as a measure of the potential for long-distance dispersal was statistically significant for the presence of *Eleocharis* and *Sagittaria* (Table 3 and 4). According to the nominal logistic regression results, quadrats at lower elevations have a higher probability of having *Eleocharis* and *Sagittaria* than quandrats at higher elevations. Distance from the river, another measure of long-distance dispersal was statistically significant for *Rhynchopora* and *Pontedaria.* Quadrats further from the river channel were more likely to have *Rhynchopora* and *Pontedaria* than those closer to the river.

Seed bank

Two indicator species, *Panicum* and *Cephalanthus* were not found in the seed bank in either the fall or spring. Although *Polygonum* seeds were present in the seed bank, they were not in enough quandrats to do a logistic regression. Similarly, *Pontedaria* was only found in the fall seed bank. Of the 5 remaining indicator species, presence in the fall seed bank was statistically significant for *Eleocharis* and *Rhychospora*. This was also true for *Rhynchospora* and *Sagittaria* in the spring seed bank. Therefore, for 3 of the 5 indicator species their presence in permanent quadrats was correlated with their presence in the seed bank (Table 3 4). The more seedlings germinated in the samples, the greater the potential for a particular area to have a species.

Graphical representations of data

The propagule data for each indicator species found statistically significant is illustrated (Figure 4-6). Each bar on the graphs represents data from one research quadrat. Figure 4 is four separate graphs, one for each indicator species and intermediate dispersal data. Data for all four indicator species showed an increased potential for a species to be found in a quadrat with greater areas of nearby remnant propagules. However, for each of the indicator species some quadrats had the species present with less nearby propagule area than other quadrats without the species. Figure 5 is two separate graphs show the relationship between distance to the river and the presence of *Rhynchospora* and *Pontedaria* in the quadrats. For both species it appears quadrats closer to the river are less likely to have the indicator species. Figure 6 is three graphs of the seed bank data. All three show greater probability a species is in a quadrat when there is more of the species in the seed bank.

Effects of Pre-Restoration Land-Use Practice

Table 5 shows the percentage of quadrats with indicator species present categorized by their pre-restoration land use practice. The wetland shrub indicator, *Cephalanthus*, is more likely to be found in quadrats, which were formerly mesophytic shrubs, than plots, which were once wet prairie. The broadleaf marsh indicators, *Sagittaria* and *Pontedaria* were more likely to be in areas formerly levee (66% and 100% respectively). *Sagittaria* was found in 78% of the quadrats found in mesophytic shrubs. Neither species was found in quadrats of the pasture and sod farmed sites. The wet-prairie indicators were found in about

60% of the pasture quadrats. Only *Panicum* and *Polygonum* were found in quadrats that were sod farmed.

Distribution of Indicator Species

Quadrats located in areas where the indicator species were found historically, i.e., prior to the channelization of the Kissimmee River, are classified as expected quadrats in Table 6. The not-expected quadrats are all other quadrats located in areas where the indicator species was not historically found. Most indicator species were just as likely to be found in expected and as not-expected quadrats. Only *Sagittaria* and *Cephalanthus* are more likely to be present in expected quadrats. For *Sagittaria,* 48% of the expected quadrats and only 6% of the not expected quadrats had the species. *Cephalanthus* was found in 82% of the expected quadrats as compared to 29% of the not expected. The percentage of quadrats with species within a short-distance was very similar between areas around expected and not expected quandrats for all species. The greatest difference between expected and not expected quandrats was for *Cephalanthus*, with 81% of the expected quadrats with *Cephalanthus* nearby for only 40% of not-expected quadrats. The percentage of quadrats with an indicator species in its seed bank was very similar for expected and not expected quadrats. The two broadleaf marsh indicators were actually more frequently found in the seed bank where they were not expected.

Table 3: Nominal logistic regression results for the wetland indicator species for the various estimates of propagule sources; elevation, distance to river channel, short-distance dispersal, intermediate-distance dispersal, and seed bank presence fall or spring.

Indicator species	Probability > X [2]	Significance
REMNANT WETLAND PROPAGULES: SHORT-DISTANCE DISPERSAL		
Wet prairie indicators		
Eleocharis	0.1471	N
Juncus	0.7544	N
Panicum	0.1379	N
Polygonum	0.0089	S
Rhynchospora	0.0094	S
Broadleaf marsh indicators		
Pontedaria	0.2173	N
Sagittaria	0.0193	S
Wetland shrub indicator		
Cephalanthus	0.0012	S
REMANANT WETLAND PROPAGULES:INTERMEDIATE-DISTANCE DISPERSAL		
Wet prairie indicators		
Eleocharis	0.0463	S
Juncus	0.5752	N
Panicum	0.3860	N
Polygonum	0.6293	N
Rhynchospora	0.0628	SU
Broadleaf marsh indicators		
Pontedaria	0.0584	S
Sagittaria	0.0921	SU
Wetland shrub indicator		
Cephalanthus	0.3438	N

[2] X^2 results abbreviations; 95-100% significant (S), 90-95%suggestive significance (SU), and < 90% no significance (N).

Table 3:(continued)

Indicator species	Probability > X^2	Significance
	LONG-DISTANCE PROPAGULES: ELEVATION	
Wet prairie indicators		
Eleocharis	0.0125	S
Juncus	0.3492	N
Panicum	0.1180	N
Polygonum	0.1180	N
Rhynchospora	0.2132	N
Broadleaf marsh indicators		
Pontedaria	0.2653	N
Sagittaria	0.0001	S
Wetland shrub indicator		
Cephalanthus	0.2941	N
	LONG-DISTANCE PROPAGULES: DISTANCE TO RIVER	
Wet prairie indicators		
Eleocharis	0.1592	N
Juncus	0.1669	N
Panicum	0.1990	N
Polygonum	0.6817	N
Rhynchospora	0.0375	S
Broadleaf marsh indicators		
Pontedaria	0.0375	S
Sagittaria	0.2546	N
Wetland shrub indicator		
Cephalanthus	0.2302	N

[2] X^2 results abbreviations; 95-100% significant (S), 90-95%suggestive significance (SU), and < 90% no significance (N).

Table 3:(continued)

Indicator species	Probability > Chi square[2]	Significance
	SEED BANK PROPAGULES: PRESENCE IN SEED BANK (FALL)	
Wet prairie indicators		
Eleocharis	0.0960	SU
Juncus	0.4990	N
Panicum[3]	-	-
Polygonum[3]	-	-
Rhynchospora	0.00768	S
Broadleaf marsh indicators		
Pontedaria	0.96010	N
Sagittaria	0.93500	N
	SEED BANK PROPAGULES: PRESENCE IN SEED BANK (SPRING)	
Wet prairie indicators		
Eleocharis	0.3186	N
Juncus	0.9406	N
Panicum[3]	-	-
Polygonum[3]	-	-
Rhynchospora	0.0878	SU
Broadleaf marsh indicators		
Pontedaria	-	-
Sagittaria	0.0082	S

[2] Chi square 95-100% significant (S), 90-95% suggestive (SU), and < 90% not significant (N)
[3] Indicator species was not found in the seed bank or not present in enough plots to incorporate into a meaningful nominal logistic regression analysis.

Table 4: The number of indicator species with significant logistic regressions, for each potential source of propagules of a species in the quadrats.

Estimate of propagule source	Fraction of species found significant	Species found statistically significant
Remnant wetland propagules		
Intermediate-distance dispersal	4/8	*Eleocharis, Rhynchospora, Pontedaria, Sagittaria*
Short-distance dispersal	4/8	*Polygonum, Rhynchospora, Cephalanthus, Sagittaria*
Long-distance dispersal propagules		
Elevation of quadrat	2/8	*Eleocharis, Sagittaria*
Distance to river channel	2/8	*Rhynchospora, Pontedaria*
Seed bank propagules		
Found in the fall seed bank (1998)	2/5	*Eleocharis, Rhynchospora*
Found in the spring seed bank (1999)	2/5	*Rhynchospora, Sagittaria*
Found in either seed banks	3/5	*Eleocharis, Rhynchospora, Sagittaria*

Table 5: Wetland areas dominated prior to channelization by a given vegetation type and percentage of quadrats with indicator species present in the summer of 2001, in each area with a different pre-restoration land use practice.

Indicator Species	Pre-restoration land-use practice	Percentage of quadrats	Fraction of quadrats
Wetland shrub			
Cephalanthus occidentalis	Mesophytic shrubs	100%	6/6
	Wet prairie	60%	3/5
	Total	82%	9/11
Broadleaf marsh			
Pontedaria cordata	Levee	66%	2/3
	Mesophytic shrubs	22%	2/9
	Pasture	0%	0/6
	Sod farm	0%	0/3
	Total	20%	4/21
Sagittaria lancifolia	Levee	100%	3/3
	Mesophytic shrubs	78%	7/9
	Pasture	0%	0/6
	Sod Farm	0%	0/3
	Total	48%	10/21
Wet prairie			
Eleocharis spp.	Pasture	44%	8/18
	Sod farm	33%	1/3
	Total	43%	9/21
Juncus effucus	Pasture	61%	11/18
	Sod farm	0%	0/3
	Total	52%	11/21
Panicum hemitomon	Pasture	56%	10/18
	Sod farm	67%	2/3
	Total	57%	12/21

Table 5:(continued)

Indicator Species	**Pre-restoration land-use practice**	**Percentage of quadrats**	**Number of quadrats**
Wet prairie (continued)			
Polygonum spp.	Pasture	61%	11/18
	Sod farm	33%	1/3
	Total	57%	12/21
Rhynchospora inudata	Pasture	61%	11/18
	Sod farm	0%	0/3
	Total	52%	11/21

Table 6: Percent of permanent quadrats with indicator species in which they were or were not expected based on pre-channelization vegetation. Percent of permanent quadrats in which did or did not have the indicator species in adjacent wetlands; and percent of permanent quadrats in which indicator species were found or were not found in the seed bank fall/1998 or spring /1999.

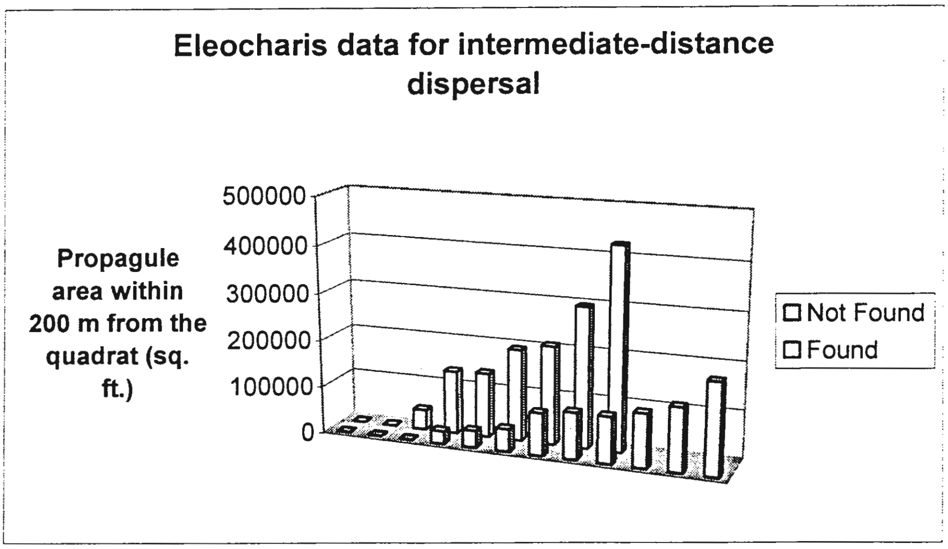
Indicator species	Percent permanent quadrats which species is expected	Percentage of all other quadrats in which species is not expected
	PERMENANT QUANDRAT VEGETATION	
Wet prairie indicators		
Eleocharis	58%	68%
Juncus	58%	35%
Panicum	58%	72%
Polygonum	58%	53%
Rhynchospora	58%	38%
Broadleaf marsh indicators		
Pontedaria	20%	34%
Sagittaria	48%	6%
Wetland shrub indicator		
Cephalanthus	82%	29%
	ADJACENT REMNANT WETLANDS	
Wet prairie indicators		
Eleocharis	48%	13%
Juncus	71%	66%
Panicum	67%	69%
Polygonum	33%	47%
Rhynchospora	62%	38%
Broadleaf marsh indicators		
Pontedaria	81%	59%
Sagittaria	86%	55%
Wetland shrub indicator		
Cephalanthus	81%	40%

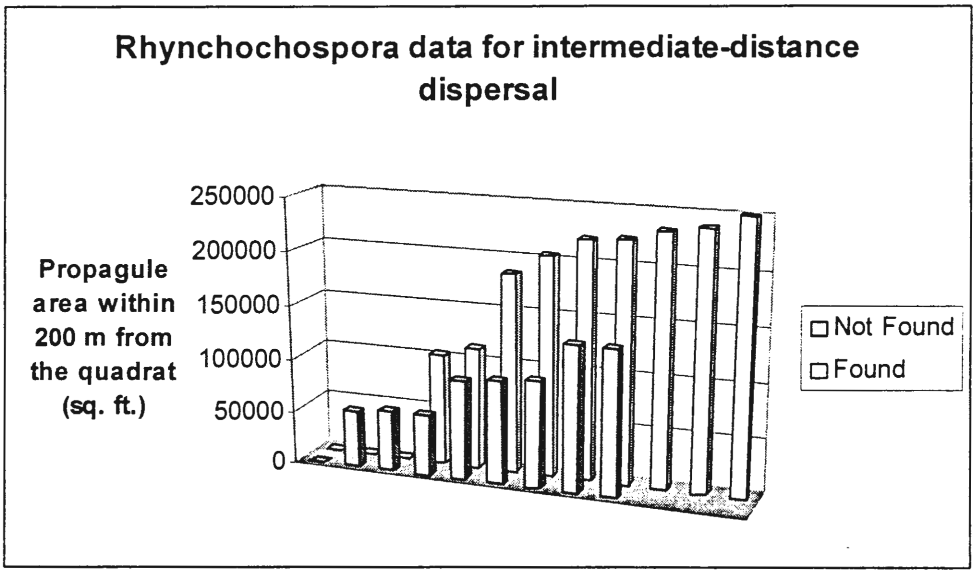
Table 6:(continued)

Indicator species	Percent permanent quadrats which species is expected	Percentage of all other quadrats in which species is not expected
SEED BANK: EITHER FALL 1998 OR SPRING 1999		
Wet prairie indicators		
Eleocharis	100%	69%
Juncus	90%	81%
Panicum[4]	-	-
Polygonum	5%	16%
Rhynchospora	95%	88%
Broadleaf marsh indicators		
Pontedaria	19%	31%
Sagittaria	19%	31%
Wetland shrub indicator		
Cephalanthus[4]	-	-

4 Indicator species was not found in the seed bank in the spring or the fall.

Figure 4: Graphical representation of intermediate dispersal data for quadrats the indicator species *Eleocharis, Rhynchospora, Pontedaria, and Sagittaria* were found and not found in.





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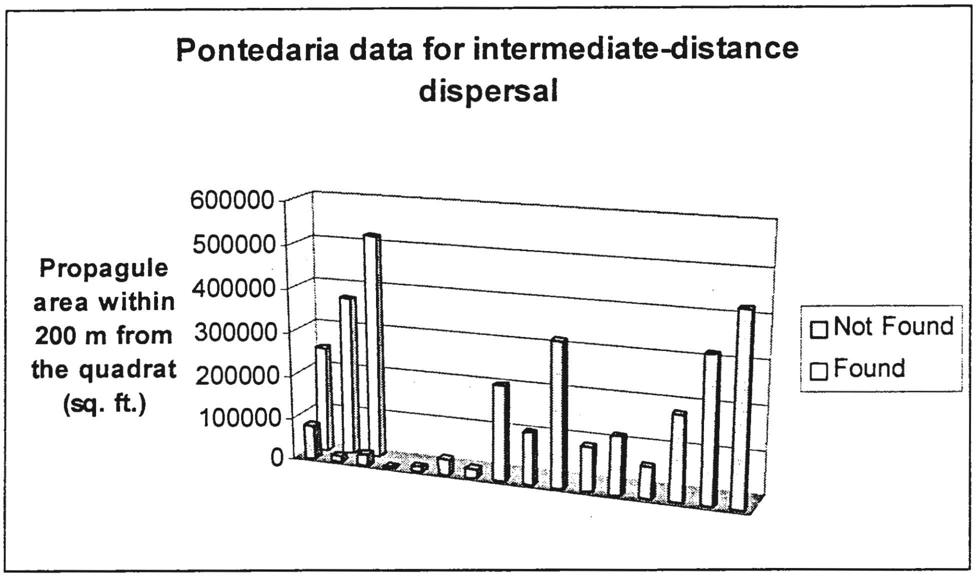


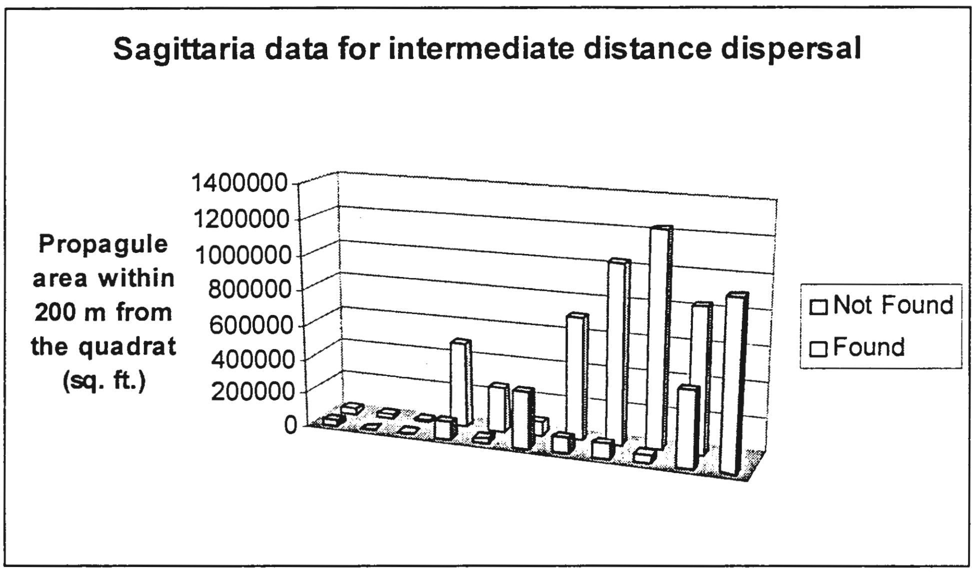
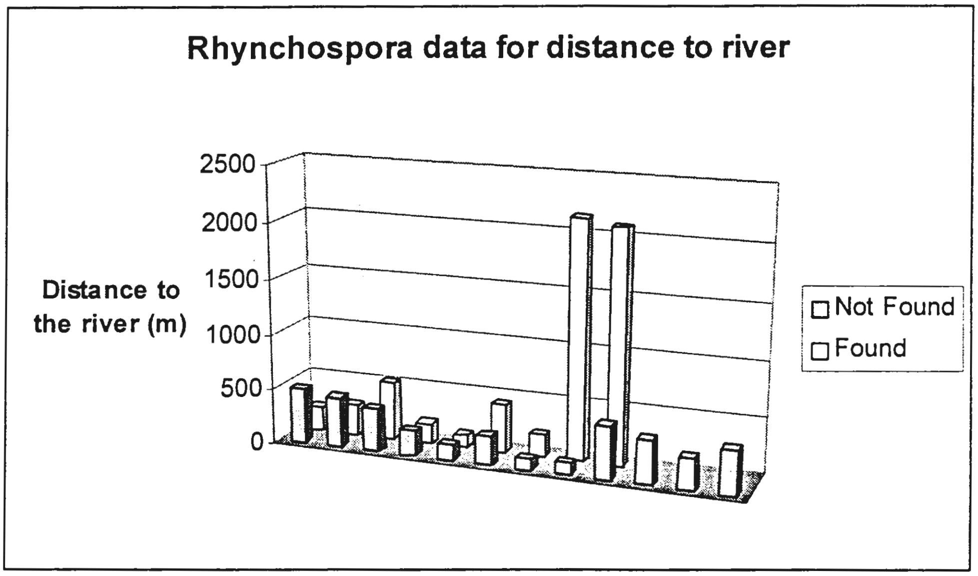


Figure 5: Graphical representation of distance to river data for quadrats the indicator species *Rhynchospora* and *Pontedaria* were found and not found in.



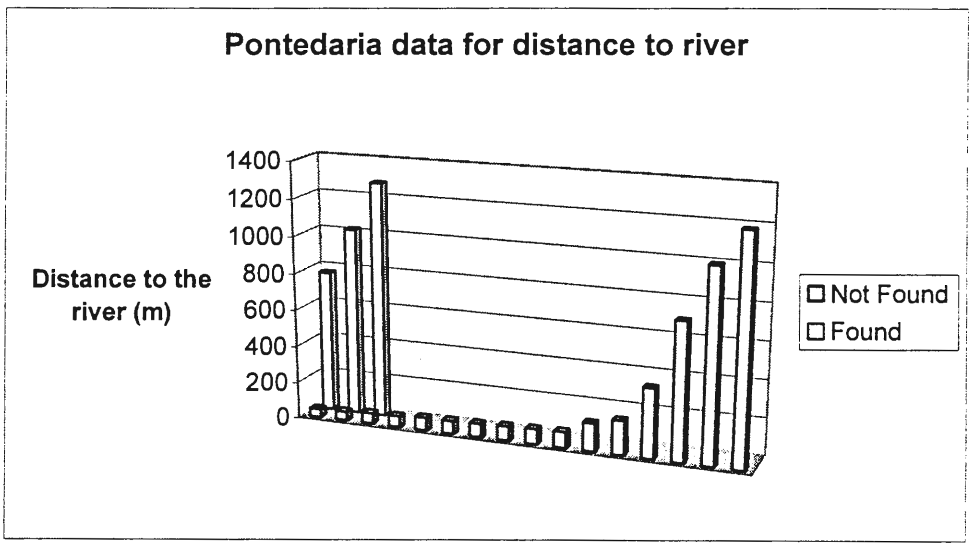
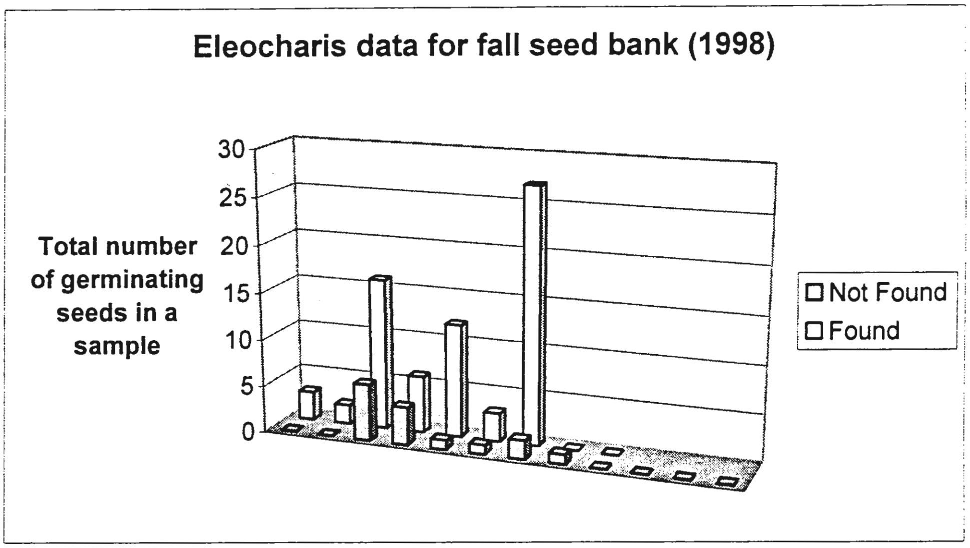
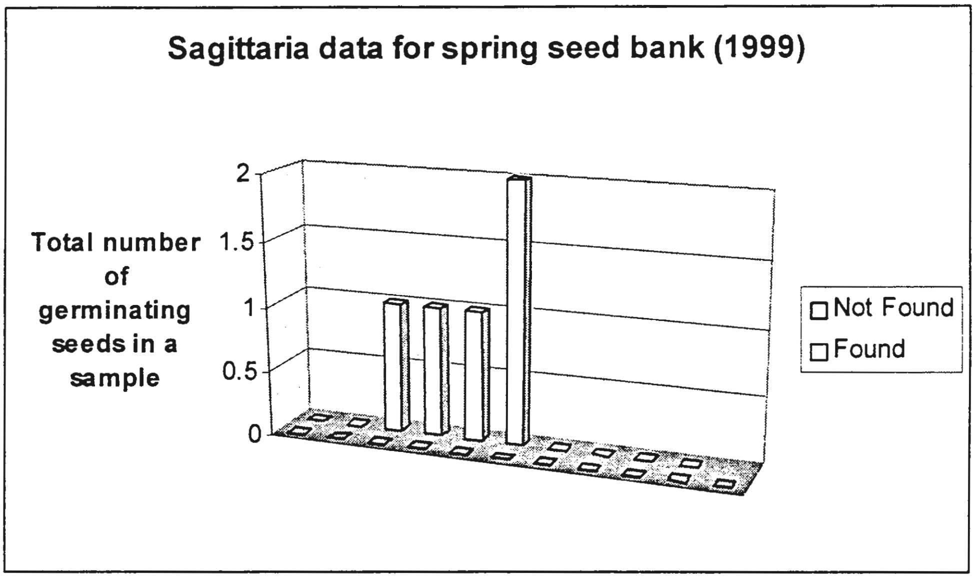


Figure 6: Graphical representation of distance to river data for quadrats the indicator species *Rhynchospora* and *Pontedaria* were found and not found in.





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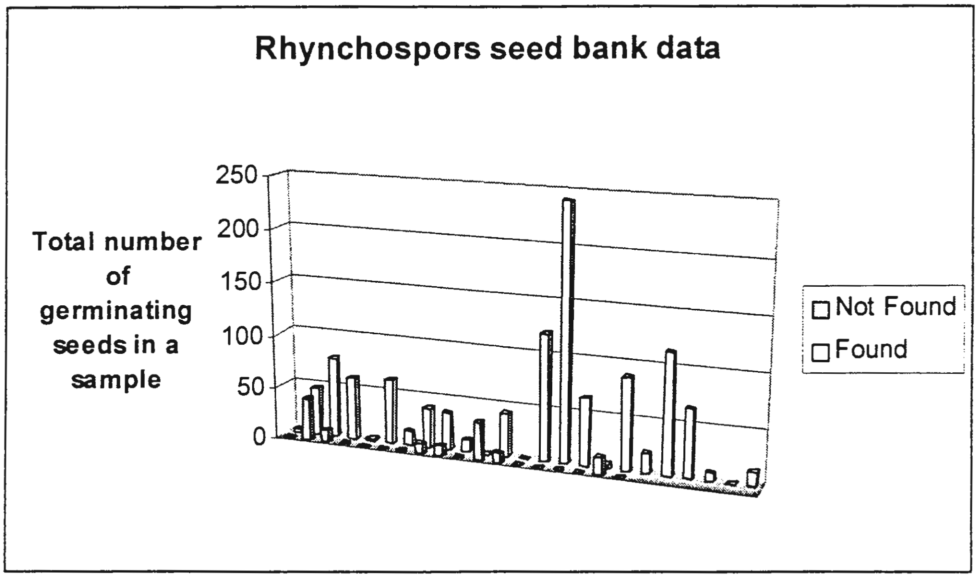

DISCUSSION

Sources of Propagules on the Kissimmee River Floodplain

This study investigated three potential sources of propagules by which species formerly dominating the three major wetland communities might become reestablished on the Kissimmee River floodplain; dispersal from remnant populations of wetlands on the floodplain, long-distance dispersal of seeds and propagules from upstream, and seed banks. All three sources of propagules were associated with the presence of least two-indicator species in the research quadrats. The presence of indicator species in remnant wetlands was more often associated with the presence of the indicator species in the permanent quadrats, *Eleocharis, Rhynchospora, Pontedaria, Sagittaria, Polygonum*, and *Cephalanthus*, (6 of 8 indicator species) than the possible long-distance dispersal of propagules, *Eleocharis, Rhynchospora, Pontedaria,* and *Sagittaria* (4 of 8 indicator species). Presence in the seed bank was associated with reestablishment of *Eleocharis*, *Rhynchospora,* and *Sagittaria* (3 of 5 indicator species), in the permanent quadrats. These data indicate all three sources of propagules will be involved in the in the reestablishment of wetland vegetation on the Kissimmee River floodplain.

The importance of these three sources of propagules for the reestablishment of wetland communities on the floodplain has been recognized by Toth (1999). As prolonged hydroperiods of 9-12 months are restored, *Cephalanthus,* is expected to reestablish primarily through remnant propagules or vegetative growth of adjacent plants. The long hydroperiods are expected to eliminate the upland and mesophytic shrub species. This reestablishment was expected to take 3-5 years to achieve (Toth 1999). In this study, *Cephalanthus* was more likely to be present in quadrats if remnant populations were nearby. Restoration of broadleaf marsh species was also expected to require 9-12 month hydroperiods. *Pontedaria* and *Sagittaria* were expected to reestablish from propagules from nearby remnant populations, vegetative spread from adjacent populations, and the seed bank (Toth 1999). This study suggested *Pontedaria* and *Sagittaria* were more likely to be found in quadrats with nearby remnant populations, and *Sagittaria* was more likely to be found in a quadrat if present in the seed bank. Restoration of wet prairie communities was expected to occur with 3-8 month hydroperiods. The shorter more variable hydroperiods at the edge of the floodplain allow for more diversity than found in either the wetland shrub or the broadleaf marsh communities. Wet prairie was expected to reestablish from both the seed bank propagules and nearby populations. This study found three wet prairie species, *Eleocharis, Rhynchospora*, and *Polygonum* more likely to be found in quadrats with nearby remnant populations. Also, *Eleocharis,* and *Rhynchospora* were more likely found in quadrats in which they were present in the seed bank.

These data can be used to infer which sources of propagules and seeds will be important for each particular indicator species. The indicator species for wetland shrub communities, *Cephalanthus occidentalis,* an understory shrub, propagates from seed and from adventitious roots produced in flooded conditions (Florida Department of Environmental Protection 1998). Nine of 11 quadrats studied already have this indicator species. For the two quadrats not reestablish with *Cephalanthus* , this species was not found in nearby remnant wetlands. In areas of the floodplain where no nearby remnant wetland populations exist, this species may have to rely on the long-distance dispersal of propagules from upstream. This may be problematic, as *Cephalanthus* is not widely distributed. *Cephalanthus* seed were not be found in the seed bank.

Pontedaria cordata and *Sagittaria lancifolia,* are both perennial broadleaf marsh species. Both species produce seeds; *Pontedaria* seeds are considered an important food for ducks and small mammals. *Sagittaria* emerges each year from a bulb, while *Pontedaria* has an extensive rhizome system (Florida Department of Environmental Protection 1998). The data suggest *Pontedaria* will lag behind *Sagittaria* in reestablishing historic areas of the floodplain. Only 4 of 21 quadrats have *Pontedaria*, while 10 have *Sagittaria*. Remnant wetland populations, long-distance dispersal, and the seed bank were all significant sources of propagules for *Sagittaria*, while the seed bank was not for *Pontedaria.* Neither species was present in great numbers in the seed bank (1-2 /m^2). Of the four quadrats with *Pontedaria,* all had a remnant wetland population sources nearby, but several quadrats with remnant propagules nearby had not reestablish with *Pontedaria*. All quadrats studied had *Sagittaria* in nearby remnant wetlands, therefore, long-distance dispersal will not be as necessary as other propagules sources.

Eleocharis spp., and *Rhynchospora inundata* are herbaceous wet prairie species, which primarily disperses vegetatively through rhizomes or stolons as well as seeds (Florida Department of Environmental Protection 1998). This implicates propagule sources from nearby remnant wetlands and the seed bank will be essential in the dispersal of these species. The results of this study support the potential importance of propagules from nearby remnant wetlands and the seed bank for the reestablishment for these species. Nine of 21 quadrats studied have already reestablished with *Eleocharis* and 11 of the 21 with *Rhynchospora*. Many of the quadrats not reestablished with *Eleocharis*, had few if any propagules in the seed bank or lacked nearby remnant wetland sources, similar trends are notable with *Rhynchospora*. All quadrats either have *Rhynchopora* and *Eleocharis* either in the seed bank, or in nearby wetlands, long-distance dispersal from wetlands upstream will not be necessary to reestablish these species.

Juncus effucus is a perennial wetland prairie species that spreads primarily through elongating rhizomes, *Panicum hemitomon*, a grass spreads vegetatively as well, but both also can disperse from seed. The sources of propagules for these species were not found statistically significant. However, 11 of the 21 quadrats have *Juncus,* and 12 have *Panicum.* This implies *Juncus* and *Panicum* are reestablishing quadrats as well as *Eleocharis* and *Rhynchospora.* Since, both species are widespread in the floodplain vegetation they will likely disperse into all of the historic wet prairie areas from nearby sources.

Polygonum spp. is primarily disperses via birds and mammals (Florida Department of Environmental Protection 1998). The sources of propagules studied were not statistically significant potential sources of propagules for this species. Yet 12 of 21 plots have reestablished with *Polygonum,* possibly because the species is already widely distributed throughout the floodplain and dispersal is aided by wildlife.

The Implications of Land Use

The three potential sources of propagules studied will be important for the in the reestablishment of wetland communities, but post-channelization land use practice may complicate the process. As a result of channelization wetland shrub communities were cleared and replaced by a mesophytic shrub community dominated by the exotic shrub species *Myrica ceriferia* (Wax Myrtle) or replaced by wet prairie. Reengineering of the floodplain's historic hydrology and long hydroperiods is eliminating both the wet prairie species and the mesophytic shrubs that could allow *Cephalanthus* to reestablish in the quadrats. The majority of quadrats in both mesophytic shrub communities and wet prairie communities had *Cephalanthus* present already. Wet prairies may take longer to re-establish with *Cephalanthus* because these wet prairie species can tolerate wet conditions better than mesophytic shrubs (Toth 1999).

After channelization, broadleaf marsh communities were drained and converted to cattle pasture, sod farm or became dominated by mesophytic shrub communities. The quadrats in mesophytic shrub and levee areas should become broadleaf marsh communities. Mesophytic shrubs cannot tolerate the long hydroperiods preferred by broadleaf marsh species, and will quickly be excluded. The data show the mesophytic shrub areas will return to broadleaf marsh. Quadrats in pastures were surrounded by predominately upland herbaceous species. However nearby remnant wetland propagules were available, yet *Pontedaria* and *Sagittaria* were not found in pasture quadrats. In the case of sod-farmed areas, it is possible the seed bank was lost during the removal of sod. But this cannot be determined by the data as very few seed bank propagules were found in any of the broadleaf marsh quadrats. Unlike natural disturbances, human caused disturbances such as sod–farming and cattle grazing threaten the ability of communities to resist changes and recover to their preexisting condition. These disturbances caused vast changes in the floodplain environment. In riverine systems, cattle grazing can interfere with seed germination due to trampling and compaction of soil (Makay 1990) for as long as 14 years (Magillilan and McDowell 1997). Even light grazing can significantly impact the vegetation in a wetland. The effects of cattle grazing can vary considerably due to stream bank trampling, dung, deposition, and invasion of exotic species. Farming may cause soil compaction allowing invasion of noxious weeds (Bedford et al. 1974). Sod-farming, may restrict the ability of species to reestablish in quadrats by destroying the generative ability of many types of wetlands. For example, in the bottomland cypress swamps of the southeast United States, the seed bank of the dominant native species was completely destroyed after just one year of farming (Middleton 1999b). Wetland species have traits allowing them to survive natural disturbances. Human disturbances often take long periods of time for species to recover (Middleton 1999). Former levee sites on the floodplain allowed wet prairie to occupy relatively low elevations. The longer hydroperiods will give broadleaf marsh species the opportunity to reestablish in these areas and eventually replace the wet prairie species. According to the data, most of the levee plots have both *Pontedaria* and *Sagitarria*. Broadleaf marsh species are colonizing areas of mesophytic, and wet prairie in levee plots, but not sites were human disturbance is prevalent.

After channelization, wet prairies were converted to pastures, or were sod-farmed. Wet prairie species are re-establishing in quadrats formerly pastured. Sod-farmed areas of the floodplain will be more difficult for wet prairie the re-colonize due to degradation of the seed bank and lack of remnant populations. Only *Panicum* and *Polygonum* were found in quadrats that were sod-farmed. It is likely these two species have reestablished in these sod-farmed areas so quickly, because both species were located within 100 meters of the quadrats.

There appears to be a relationship between land-use and the presence of an indicator species in a quadrat. In some areas of the floodplain, permanent quadrats were in highly degraded areas caused by human disturbance such as sod farms and cattle grazing, while other quadrats were located in nearly unaltered areas. Most wetlands do eventually recover from grazing, though this can sometimes take decades (Magillilan and McDowell 1997). Due to lack nearby propagules and the removal of the seed bank quadrats within sod-farmed areas of the floodplain, the historic wetland communities will have difficulty reestablishing. These sites will have to rely on the dispersal of long-distance propagules.

The Distribution of Indicator Species

The distribution of indicator species along the floodplain was studied to determine if seeds and relict population are where they were prior to channelization or if they are in other areas of the floodplain. Most indicator species were as just likely to be found in expected and as not-expected quadrats. Only *Sagittaria* and *Cephalanthus* are more likely to be present in expected quandrats. The percentage of quandrats with nearby remnant wetland propagules was very similar between areas around expected as not expected quadrats, for all species. The percentage of quandrats with an indicator species in its seed bank was very similar for expected and not expected. The two broadleaf marsh indicators were actually more frequently found in the seed bank of not expected quadrats. For vegetation to reestablish after a disturbance it is necessary for the wetland to either develop a seed and/ or propagule bank to be reintegrated into the landscape so seeds and propagules will refill the vegetation gaps after hydrology is restored. Restoration projects can be limited by the quality and the quantity of propagules available to regenerate vegetation after hydrological restoration (Galatowitsch and van der Valk 1996). Seeds and propagules are available to reestablish the Kissimmee River floodplain. Not all, the remnant populations, seeds, and propagules are in their historic locations but flood pulsing will sort out the species in areas suitable for them to invade and survive. Species may reestablish in the same areas they historically occupied. Ultimately, interconnectedness is the determinant of the natural ability of seeds or propagules to disperse and invade new areas (Middleton 1999). Wetland species will invade these areas if conditions are suitable, which may result in species reestablishing in new locations, they historically did not occupy.

Shortcomings of the Study

Although the results of this study support the expectations of how the species will reestablish on the floodplain. The estimates used for each of the propagule sources may be confounded and/or overly simplified. The seed bank data was a direct estimate of the presence and abundance of seeds in a quandrat. It is not known how long they have been there or where they came from. The seed bank also could include seeds from nearby remnant wetlands and even from upstream dispersed by flooding events. Middleton (2000) found while that species similarity between water-dispersed seeds and the seed bank was high at low elevations that were frequently flooded, similarity was low at higher elevations that were not frequently flooded. This indicates seeds can be dispersed by water from upstream and be incorporated in the seed bank. The only assumption made was the viability of the seed. The species studied did not have the same persistence or longevity.

Relict wetlands are potential sources of propagules but seeds still have to disperse, establish and survive in the permanent quadrat. It may be problematic using existing vegetation in the wetlands as estimates of propagules, as they may have just reestablished in those locations as well. Remnant wetland propagules may be associated with the seed bank in a quadrat and also may have come from propagules upstream.

Long-distance propagule sources are assumed using elevation and distance to the river as estimates of long-distance propagule dispersal. These estimates required two additional assumptions. One, floodwaters contain viable propagules of all the wetland indicator species evaluated and that populations of these wetland species are re-established periodically at low densities on throughout the floodplain. Second, the water disperses the propagules in a gradient over the floodplain concentrating propagules in flood prone areas at lower elevations and closer to the river.

The results of this study may be misleading due to these assumptions, particularly those made in estimating long-distance dispersal. The assumption all indicator species are present in the floodwaters may not be accurate. The vegetation composition immediately upriver from the quadrats was not assessed. Andersson et al.(2000), studied the effects of river fragmentation on plant dispersal and riparian flora in two adjacent rivers and Northern Sweden. Their study suggested propagules deposited and species richness were higher in a free-flowing river than in a regulated river. Floristic continuity or species similarity between upstream and downstream was higher in the free-flowing river. Upstream and downstream similarities decrease after regulation, with no means of long-distance dispersal, local floral must depend only on nearby contributions (Andersson et al. 2000). This implies the upstream and downstream similarities will increase with the restoration of the hydrology of the Kissimmee River, but propagules from far upstream may not be able to reach the Pool C because of remaining water control structures.

The assumption water disperses the propagules in a gradient over the floodplain concentrating propagules more in flood prone areas may also be flawed. Although the elevation gradient over the study area was very minimal, the historic inundation frequencies varied greatly over the elevations as much as 70% with in one meter of elevation difference(Toth et al. 1995). Consequently, elevation differences do result in great differences in inundation frequencies. Floodwaters may inundate the floodplain predictable gradient based on distance for the river channel and elevation, but it does not necessarily follow seeds and propagules will follow this gradient. Experimental release of propagules showed a leptokurtic or a distribution with a high peak in the dispersal pattern with large variation (Johansson and Nilsson 1993). This variation was attributed to physical properties of a river depth, width, wave action, and debris. Some studies indicate distance to a river channel may effect the species richness of a floodplain due to transport of seed and propagules, distance from the stream appeared to have some effect on species richness in floodplain forests, Vermont (Hughes and Cass 1997). Even though trends were evident, overall patterns of species distribution and distance to river were more complex. Other factors such as micotopography, substrate heterogeneity, propagule deposition, and unpredictable biotic and abiotic-related disturbances complicate the pattern. Hughes and Cass (1997), suggest distance from a stream imposes a probable gradient that sustains vegetation trends within a riparian system, but these trends are complicated by local conditions and patterns affecting propagule deposition and seedling establishment. Aspects of microtopgraghy, substrate heterogeneity, debris, and other physical obstacles to dispersal were not considered in estimating long-distance dispersal.

The estimates of propagule availability for dispersal along the Kissimmee do not reflect the dispersal ability of particular wetland species expected to redevelop on the floodplain nor the germination requirements of individual species. Species' response models to disturbances often depend heavily on seed germination and dispersal characteristics (van der Valk 1981, Ellison and Bedford 1995). The dispersal ability of a species can be used to predict changes in vegetation composition of wetlands. A qualitative model of succession was developed by van der Valk (1981), based on life history traits of species in the wetland. When each species' life-span, propagule longevity and propagule establishment requirements are known, it is possible to predict future of the species after environmental conditions change. Life histories of the indicator species in this study were not included in the analysis. These estimates also exclude the impacts of other biological dispersal means such as waterfowl (Holt and van der Valk 2001), which may be important in the dispersal of *Pontedaria* and *Polygonum*.

This was a limited study of a small number of permanent quadrats or observations; only 15-21 quandrats were evaluated for each wetland community type. A larger number of observations would have been ideal and place greater confidence in the statistical results. The small number of observations also restricted choice in the statistical approach. A nominal logistic regression could be fit only with one causal variable by way of 15-20 observations, many more observations would be necessary to fit two or more causal variables together. With categorical variables used in this study, more observations of permanent quadrats would be required.

Conclusions

Three historic wetland communities on the Kissimmee River floodplain will be reestablished through natural processes after the hydrology is restored. Potential sources of propagules are dispersal of species from nearby remnant wetlands on the floodplain, long-distance dispersal from upstream, and seed banks. All three of these sources of propagules were statistically significant for the reestablishment of the indicator species studied in research quadrats. The data suggests the seed bank and remnant wetland propagules were sufficient sources for most species studied. When remnant propagules and the seed bank are lacking, species may have to rely long-distance dispersal. Long-distance dispersal is achievable since most species are distributed throughout the floodplain.

Natural restoration is a passive approach, though it is cost effective, it has limitations. The ability of a site to revegetate itself after reengineering of hydrology is often site dependent. Some areas are isolated with few remnant sources near by thus providing few propagules. Some areas on the floodplain were converted to cattle pastures and sod farms post-channelization and highly degraded. These areas may take longer to reestablish with wetland species since these will rely on dispersal of long-distance propagules.

This study had several shortcomings regarding the estimation of the propagule sources. The life histories of these indicator species were not assessed, and may be key in understanding the outcome of the reestablishment of vegetation on the floodplain. More observations would have provided greater confidence in the statistical results. Last of all, this study brought forth more questions than it answered. The final section of this paper outlines some future research thoughts on the reestablishment of wetland vegetation on the Kissimmee River floodplain.

Future Research Thoughts

- Compare the historic, post-channelization, and post-restoration biotic structure to determine if any new patterns are developing and if these patterns can be attributed to the site-specific hydroperiods, invasive species, soil conditions or post-channelization land-use.
- Determine if there are any sites on the floodplain isolated from propagule dispersal.
- Learn more about long-distance dispersal of seeds and propagules by conducting a hydrochory study on the floodplain, particularly to determine patterns for seed dispersal and what factors these patterns dependent upon, such as physical obstacles, seed or propagule buoyancy, and seasonal discharge patterns.
- Study the species richness at various elevation and distances from the river to test the Intermediate Disturbance Hypothesis, which predicts sites with an intermediate level of disturbance will have the highest amount of species richness.
- Examine the effect of increase hydroperiods on upland and mesophytic species to determine if these species will persist. If these species do persist, examine what effect they have on the restoration process and recruitment of propagules in areas.
- Test the theory of Island Biogeography on the floodplain with remnant wetland populations to predict species richness patterns.

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Appendix A-1: GPS elevation of quadrats (meters).

Quadrat #	NW corner	NE corner	SE corner	SW corner	Average
1	41.1	41	41	41	41
2	41.4	41.2	41	41	41
3	39	39.1	38.9	39.1	39
5	37.9	37.8	37.9	37.9	38
6	37.7	37.7	38.1	38.2	38
8	36.7	36.9	36.9	36.9	37
9	36.3	36.2	36.8	36.7	37
13	36.8	36.6	37.4	37.1	37
14	37	36.9	36.8	36.8	37
15	36.9	36.9	37	37	37
20	35.6	35.5	35.6	35.6	36
30	38.5	38.1	37.8	38.2	38
31	35.5	35.7	35.7	35.8	36
33	35.4	35.4	35.9	35.6	36
34	37.4	37.2	37.4	37.6	37
35	36.8	38.4	38.4	38.7	39
36	37.7	37.4	37.7	37.8	38
37	38.6	38.3	38.5	38.6	39
40	34.9	34.9	35	35	35
101	39	38.9	38.8	38.9	39
102	39.2	39.2	39	39	39
103	39.1	39.1	39.2	39.2	39
108	37.9	37.7	37.8	37.7	38
110	38	38.3	38.2	38.1	38
111	37.8	38	37.9	37.9	38
116	36.8	36.8	36.6	36.5	37
122	37.9	37.8	37.7	38	38
123	38.7	38.4	38.6	38.6	39
125	39.3	39.1	39	39.2	39
136	35.6	35.6	35.7	35.7	36
140	36.7	36.5	36.4	36.7	37
163	34.6	34.7	34.1	34.2	34
165	34.4	34.5	34.5	34.6	35

Appendix A-1:(continued).

Quadrat #	NW corner	NE corner	SE corner	SW corner	Average
166	34.3	34.6	34.2	34.6	34
169	34.4	34.3	34.3	34.5	34
171	34.3	34	34	34.2	34
172	34.3	33.9	34.1	34.2	34
174	36.4	36.5	36.2	36.2	36
176	36.4	36.2	36.3	36.3	36
178	35.4	35.6	35.5	35.4	35
179	35.5	35.5	35.6	35.5	36
180	36.1	36	35.7	35.7	36
182	36.4	36.4	36.3	36.2	36
202	41.3	41.1	40.5	41	41
217	35.4	35.7	35.9	35.5	36
218	35.7	35.6	35.4	35.7	36
222	37.2	37.2	37.2	37.3	37
223	37.5	37.5	37.1	37.3	37
224	36.6	36.3	35.9	36.6	36
348	35.3	35.6	35.5	35.1	35
350	35.2	34.9	35.1	35.1	35
351	34.8	34.5	34.3	34.4	35
352	.35.2	35	34.6	34.4	35

Appendix A-2: Wetland shrub permanent quadrats expected to reestablish with *Cephalanthus*. A "*" denotes quadrat is reestablished with the indicator species.

Research quadrat #	Site location in Pool C[i]	Post-1972 land-use practice[ii]	Elevation (m)	Distance to the river (m)	Remnant wetlands: < 100 m away (Y/N)	Remnant wetlands: < 200 m away (sq. ft)
8*	NC Pool Shrob	Meso Shrubs	37	115	Y	0
9*	NC Pool Shrob	Meso Shrubs	37	111	Y	0
13*	NC Pool Shrob	Meso Shrubs	37	175	Y	0
14*	NC Pool Shrob	Meso Shrubs	37	80	Y	0
15*	NC Pool Shrob	Meso Shrubs	37	116	Y	0
20*	Montsdeoca Past	Wet Prairie	36	201	Y	17971
31*	Montsdeoca Past	Wet Prairie	36	94	Y	0
33	Montsdeoca Past	Wet Prairie	36	129	N	0
40*	Montsdeoca Past	Wet Prairie	35	110	Y	2577
116*	NC Pool Shrob	Meso Shrubs	37	95	Y	0
136	Montsdeoca Past	Wet Prairie	36	46	N	0

[i] Site locations within Pool C of the Kissimmee River floodplain abbreviations: NW Pool C Pasture (NWPasture), Montsdeoca Pasture (Montsdeoca Past), NW Pool C Pasture (NW Pasture), and Mac Authur Impoundment (Mac Authur Imp.).

[ii] Post-1972 land- use practice abbreviation: Mesophytic Shrubs (Meso Shrubs).

Appendix A-3: Broadleaf marsh permanent quadrats expected to reestablish with *Pontedaria.* A "*" denotes quadrat is reestablished with the indicator species.

Research quadrat #	Site location in Pool C[i]	Post-1972 land-use practice[ii]	Elevation (m)	Distance to the river (m)	Remnant wetlands: < 100 m away (Y/N)	Remnant wetlands: < 200 m away (sq. ft)	Seed bank (Fall 1997) seeds/m^2
108	NE Sod Farm	Sod Farm	38	375	Y	116117	0
110	NE Sod Farm	Sod Farm	38	185	Y	80537	0
111	NE Sod Farm	Sod Farm	38	152	Y	13878	0
163	Pool C Wax Myrtle	Meso Shrubs	34	88	Y	25104	1
165	Pool C Wax Myrtle	Meso Shrubs	35	71	Y	3598	0
166	Pool C Wax Myrtle	Meso Shrubs	34	46	N	11810	0
169	Pool C Wax Myrtle	Meso Shrubs	34	75	Y	36239	1
171*	Pool C Wax Myrtle	Meso Shrubs	34	72	Y	53176	1
172	Pool C Wax Myrtle	Meso Shrubs	34	80	Y	21141	2
174	EC Slough	Cattle pasture	36	58	Y	220448	0
176	EC Slough	Cattle pasture	36	60	Y	121912	0
178	EC Slough	Cattle pasture	35	84		332960	0
179	EC Slough	Cattle pasture	36	70	N	103508	0
180	EC Slough	Cattle pasture	36	47	N	134646	0
182	EC Slough	Cattle pasture	36	50	N	73310	0
217	Mac Aurthur Imp	Meso Shrubs	36	1029	Y	197108	0
218*	Mac Aurthur Imp	Meso Shrubs	36	1275	Y	246322	0
348	Mac Aurthur Imp	Meso Shrubs	35	736	Y	335119	0
350*	Mac Aurthur Imp	Levee	35	767	Y	369301	0
351*	Mac Aurthur Imp	Levee	35	1015	Y	516122	0
352	Mac Aurthur Imp	Levee	35	1213	Y	435602	0

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[i] Site locations within Pool C of the Kissimmee River floodplain abbreviations: NW Pool C Pasture (NWPasture), Montsdeoca Pasture (Montsdeoca Past), NW Pool C Pasture (NW Pasture), and Mac Authur Impoundment (Mac Authur Imp.) East Central Slough(EC Slough)

[ii] Post-1972 land- use practice abbreviation: Mesophytic Shrubs (Meso Shrubs).

Appendix A-3: Broadleaf marsh permanent quadrats expected to reestablish with *Sagittaria.* A "*" denotes quadrat is reestablished with the indicator species.

Research quadrat #	Site location in Pool C[i]	Post-1972 land-use practice[ii]	Elevation (m)	Distance to the river (m)	Remnant wetlands: < 100 m away (Y/N)	Remnant wetlands: < 200 m away (sq. ft)	Seed bank (Fall 1997) seeds/m^2	Seed bank (Spring 1997) seeds/m^2
108	NE Sod Farm	Sod Farm	38	375	Y	31599	3	0
110	NE Sod Farm	Sod Farm	38	185	Y	801	0	0
111	NE Sod Farm	Sod Farm	38	152	N	3874	0	0
163*	Pool C Wax Myrtle	Meso Shrubs	34	88	Y	3291	0	0
165*	Pool C Wax Myrtle	Meso Shrubs	35	71	Y	17615	0	0
166*	Pool C Wax Myrtle	Meso Shrubs	34	46	Y	11820	0	1
169*	Pool C Wax Myrtle	Meso Shrubs	34	75	Y	496412	0	1
171*	Pool C Wax Myrtle	Meso Shrubs	34	72	Y	25709	1	1
172*	Pool C Wax Myrtle	Meso Shrubs	34	80	Y	78308	2	2
174	EC Slough	Cattle pasture	36	58	Y	99214	0	0
176	EC Slough	Cattle pasture	36	60	Y	30758	0	0
178	EC Slough	Cattle pasture	35	84	N	326414	0	0
179	EC Slough	Cattle pasture	36	70	N	88081	0	0
180	EC Slough	Cattle pasture	36	47	Y	82976	0	0
182	EC Slough	Cattle pasture	36	50	Y	48639	0	0
217	Mac Aurthur Imp	Meso Shrubs	36	1029	Y	4357	0	0
218*	Mac Aurthur Imp	Meso Shrubs	36	1275	Y	708628	0	0
348	Mac Aurthur Imp	Meso Shrubs	35	736	Y	962280	0	0
350*	Mac Aurthur Imp	Levee	35	767	Y	103004	0	0
351*	Mac Aurthur Imp	Levee	35	1015	Y	1237070	0	0
352*	Mac Aurthur Imp	Levee	35	1213	Y			

[i] Site locations within Pool C of the Kissimmee River floodplain abbreviations: NW Pool C Pasture (NWPasture), Montsdeoca Pasture (Montsdeoca Past), NW Pool C Pasture (NW Pasture), and Mac Authur Impoundment (Mac Authur Imp.) East Central Slough(EC Slough)
[ii] Post-1972 land- use practice abbreviation: Mesophytic Shrubs (Meso Shrubs).

Appendix A-4. : Wet prairie permanent quadrats expected to reestablish with *Eleocharis*. A "*" denotes quadrat is reestablished with the indicator species.

Research quadrat #	Site location in Pool C[i]	Post-1972 land-use practice	Elevation (m)	Distance to the river (m)	Remnant wetlands: < 100 m away (Y/N)	Remnant wetlands: < 200 m away (sq. ft)	Seed bank (Fall 1997) seeds/m^2	Seed bank (Spring 1997) seeds/m^2
1	NW Pasture	Cattle pasture	41	495	N	97, 652	0	6
2	NW Pasture	Cattle pasture	41	451	N	112, 295	0	13
3	NW Pasture	Cattle pasture	39	387	N	97,779	6	30
5*	NW Pasture	Cattle pasture	38	227	Y	207, 023	3	1
6*	NW Pasture	Cattle pasture	38	142	Y	135, 333	2	7
30*	Montsdeoca Past.	Cattle pasture	38	259	Y	295, 398	16	31
34	Montsdeoca Past.	Cattle pasture	37	223	Y	190, 404	4	20
35*	Montsdeoca Past.	Cattle pasture	39	273	N	132, 334	6	4
36	Montsdeoca Past.	Cattle pasture	38	96	N	25, 868	1	8
37	Montsdeoca Past.	Cattle pasture	39	106	N	35, 160	1	1
101*	NE Sod Farm	Sod farm	39	521	N	41, 646	12	0
102	NE Sod Farm	Sod farm	39	475	N	0	2	0
103	NE Sod Farm	Sod farm	39	400	N	0	1	0
122*	NW Pasture	Cattle pasture	38	180	N	192, 989	3	2
123	NW Pasture	Cattle pasture	39	286	N	132, 653	0	1
125	NW Pasture	Cattle pasture	39	391	N	89, 075	0	7
140*	Mac Aurthur Imp.	Cattle pasture	35	110	Y	424, 499	27	134
202	NW Pasture	Cattle pasture	47	434	Y	47, 077	0	6
222	Mac Aurthur Imp.	Cattle pasture	37	201	Y	0	0	3
223*	Mac Aurthur Imp.	Cattle pasture	37	2145	Y	0	0	1
224*	Mac Aurthur Imp.	Cattle pasture	36	2092	Y	0	0	1

[i] Site locations within Pool C of the Kissimmee River floodplain abbreviations: NW Pool C Pasture (NWPasture), Montsdeoca Pasture (Montsdeoca Past), NW Pool C Pasture (NW Pasture), and Mac Authur Impoundment (Mac Authur Imp.).

Appendix A-4. : Wet prairie permanent quadrats expected to reestablish with *Juncus.* A "*" denotes quadrat is reestablished with the indicator species.

Research quadrat #	Site location in Pool C[i]	Post-1972 land-use practice	Elevation (m)	Distance to the river (m)	Remnant wetlands: < 100 m away (Y/N)	Remnant wetlands: < 200 m away (sq. ft)	Seed bank (Fall 1997) seeds/m^2	Seed bank (Spring 1997) seeds/m^2
1*	NW Pasture	Cattle pasture	41	495	N	112450	1	0
2	NW Pasture	Cattle pasture	41	451	N	99729	3	0
3*	NW Pasture	Cattle pasture	39	387	N	135139	1	1
5*	NW Pasture	Cattle pasture	38	227	Y	237695	0	0
6	NW Pasture	Cattle pasture	38	142	Y	18918	6	2
30	Montsdeoca Past.	Cattle pasture	38	259	Y	0	3	0
34	Montsdeoca Past.	Cattle pasture	37	223	Y	0	0	3
35*	Montsdeoca Past.	Cattle pasture	39	273	N	0	32	14
36	Montsdeoca Past.	Cattle pasture	38	96	N	95747	1	8
37	Montsdeoca Past.	Cattle pasture	39	106	N	56913	5	0
101	NE Sod Farm	Sod farm	39	521	N	91647	0	0
102	NE Sod Farm	Sod farm	39	475	N	56474	0	1
103	NE Sod Farm	Sod farm	39	400	N	52765	0	0
122*	NW Pasture	Cattle pasture	38	180	Y	22347	0	0
123	NW Pasture	Cattle pasture	39	286	N	204340	1	5
125*	NW Pasture	Cattle pasture	39	391	N	135621	4	4
140*	Mac Aurthur Imp.	Cattle pasture	35	110	Y	0	0	0
202*	NW Pasture	Cattle pasture	47	434	Y	104256	1	1
222*	Mac Aurthur Imp.	Cattle pasture	37	201	Y	232382	1	1
223*	Mac Aurthur Imp.	Cattle pasture	37	2145	Y	220739	1	1
224*	Mac Aurthur Imp.	Cattle pasture	36	2092	Y	2496635	0	0

[i] Site locations within Pool C of the Kissimmee River floodplain abbreviations: NW Pool C Pasture (NWPasture), Montsdeoca Pasture (Montsdeoca Past), NW Pool C Pasture (NW Pasture), and Mac Authur Impoundment (Mac Authur Imp.).

Appendix A-4. : Wet prairie permanent quadrats expected to reestablish with *Panicum*. A "*" denotes quadrat is reestablished with the indicator species.

Research quadrat #	Site location in Pool C[i]	Post-1972 land-use practice	Elevation (m)	Distance to the river (m)	Remnant wetlands: < 100 m away (Y/N)	Remnant wetlands: < 200 m away (sq. ft)
1	NW Pasture	Cattle pasture	41	495	N	37661
2*	NW Pasture	Cattle pasture	41	451	N	35022
3	NW Pasture	Cattle pasture	39	387	N	38047
5*	NW Pasture	Cattle pasture	38	227	N	301746
6*	NW Pasture	Cattle pasture	38	142	Y	321116
30*	Montsdeoca Past.	Cattle pasture	38	259	Y	268135
34	Montsdeoca Past.	Cattle pasture	37	223	Y	227612
35*	Montsdeoca Past.	Cattle pasture	39	273	Y	175355
36	Montsdeoca Past.	Cattle pasture	38	96	Y	206703
37	Montsdeoca Past.	Cattle pasture	39	106	Y	182129
101*	NE Sod Farm	Sod farm	39	521	Y	91583
102	NE Sod Farm	Sod farm	39	475	N	69594
103*	NE Sod Farm	Sod farm	39	400	N	36855
122	NW Pasture	Cattle pasture	38	180	Y	318360
123*	NW Pasture	Cattle pasture	39	286	Y	109220
125	NW Pasture	Cattle pasture	39	391	Y	42375
140*	Mac Aurthur Imp.	Cattle pasture	35	110	Y	381070
202	NW Pasture	Cattle pasture	47	434	N	44942
222*	Mac Aurthur Imp.	Cattle pasture	37	201	Y	88013
223*	Mac Aurthur Imp.	Cattle pasture	37	2145	Y	51116
224*	Mac Aurthur Imp.	Cattle pasture	36	2092	Y	202701

[i] Site locations within Pool C of the Kissimmee River floodplain abbreviations: NW Pool C Pasture (NWPasture), Montsdeoca Pasture (Montsdeoca Past), NW Pool C Pasture (NW Pasture), and Mac Authur Impoundment (Mac Authur Imp.).

Appendix A-4: Wet prairie permanent quadrats expected to reestablish with *Polygonum*. A "*" denotes quadrat is reestablished with the indicator species.

Research quadrat #	Site location in Pool C[i]	Post-1972 land-use practice	Elevation (m)	Distance to the river (m)	Remnant wetlands: < 100 m away (Y/N)	Remnant wetlands: < 200 m away (sq. ft)
1	NW Pasture	Cattle pasture	41	495	N	39049
2	NW Pasture	Cattle pasture	41	451	N	40762
3*	NW Pasture	Cattle pasture	39	387	N	34698
5*	NW Pasture	Cattle pasture	38	227	Y	96821
6*	NW Pasture	Cattle pasture	38	142	Y	160691
30*	Montsdeoca Past.	Cattle pasture	38	259	Y	0
34*	Montsdeoca Past.	Cattle pasture	37	223	Y	16833
35*	Montsdeoca Past.	Cattle pasture	39	273	Y	0
36	Montsdeoca Past.	Cattle pasture	38	96	N	0
37	Montsdeoca Past.	Cattle pasture	39	106	N	0
101	NE Sod Farm	Sod farm	39	521	N	64928
102	NE Sod Farm	Sod farm	39	475	N	98342
103*	NE Sod Farm	Sod farm	39	400	Y	81761
122	NW Pasture	Cattle pasture	38	180	Y	111563
123	NW Pasture	Cattle pasture	39	286	Y	70582
125*	NW Pasture	Cattle pasture	39	391	Y	35461
140*	Mac Aurthur Imp.	Cattle pasture	35	110	Y	0
202*	NW Pasture	Cattle pasture	47	434	Y	24648
222*	Mac Aurthur Imp.	Cattle pasture	37	201	Y	0
223	Mac Aurthur Imp.	Cattle pasture	37	2145	Y	0
224*	Mac Aurthur Imp.	Cattle pasture	36	2092	Y	0

[i] Site locations within Pool C of the Kissimmee River floodplain abbreviations: NW Pool C Pasture (NWPasture), Montsdeoca Pasture (Montsdeoca Past), NW Pool C Pasture (NW Pasture), and Mac Authur Impoundment (Mac Authur Imp.).

Appendix A-4: Wet prairie permanent quadrats expected to reestablish with *Rhynchospora*. A "*" denotes quadrat is reestablished with the indicator species.

Research quadrat #	Site location in Pool C[i]	Post-1972 land-use practice	Elevation (m)	Distance to the river (m)	Remnant wetlands: < 100 m away (Y/N)	Remnant wetlands: < 200 m away (sq. ft)	Seed bank (Fall 1997) seeds/m^2	Seed bank (Spring 1997) seeds/m^2
1*	NW Pasture	Cattle pasture	41	495	N	56474	3	0
2	NW Pasture	Cattle pasture	41	451	N	52765	1	1
3	NW Pasture	Cattle pasture	39	387	Y	223547	41	37
5*	NW Pasture	Cattle pasture	38	227	N	20340	46	120
6*	NW Pasture	Cattle pasture	38	142	N	135621	77	241
30	Montsdeoca Past.	Cattle pasture	38	259	Y	0	60	65
34	Montsdeoca Past.	Cattle pasture	37	223	Y	104256	12	10
35*	Montsdeoca Past.	Cattle pasture	39	273	Y	232382	2	4
36	Montsdeoca Past.	Cattle pasture	38	96	Y	220739	1	0
37	Montsdeoca Past.	Cattle pasture	39	106	Y	2496635	0	0
101	NE Sod Farm	Sod farm	39	521	N	91647	0	0
102	NE Sod Farm	Sod farm	39	475	N	56474	1	0
103	NE Sod Farm	Sod farm	39	400	N	52765	10	17
122*	NW Pasture	Cattle pasture	38	180	Y	223547	62	88
123*	NW Pasture	Cattle pasture	39	286	N	204340	14	19
125	NW Pasture	Cattle pasture	39	391	Y	135621	10	0
140*	Mac Aurthur Imp.	Cattle pasture	35	110	Y	0	38	114
202*	NW Pasture	Cattle pasture	47	434	Y	104256	36	65
222*	Mac Aurthur Imp.	Cattle pasture	37	201	Y	232382	12	8
223*	Mac Aurthur Imp.	Cattle pasture	37	2145	Y	220739	0	0
224*	Mac Aurthur Imp.	Cattle pasture	36	2092	Y	249635	42	13

[i] Site locations within Pool C of the Kissimmee River floodplain abbreviations: NW Pool C Pasture (NWPasture), Montsdeoca Pasture (Montsdeoca Past), NW Pool C Pasture (NW Pasture), and Mac Authur Impoundment (Mac Authur Imp.).

Appendix B: My photos of the Kissimmee River

Page 61: Traveling through the meandering river channel on a sunny afternoon. Broadleaf marsh species, *Pontedaria cordata,* located on the right side of the bank, at center of photo.

Page 62: Mounds of excavated spoil along a channelized segment of the Kissimmee River. These mounds will be pushed back into the river channel as part of the restoration project.

Page 63: Cattle grazing the banks of the Kissimmee River accompanied by cattle egrets.

Page 64: Wax myrtle beginning to die back in a restored area of the floodplain.

Page 65: Beautiful summer sunrise on the of Kissimmee prairie.


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